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KEEP ON PLANNING FOR THE REAL WORLD

Climate Change calls for
Nature Based Solutions and Smart Technologies

KEEP ON PLANNING FOR THE REAL WORLD CLIMATE CHANGE CALLS FOR NATURE-BASED SOLUTIONS AND SMART TECHNOLOGIES

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PREFACE

Manfred SCHRENK,

Conference Director,
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WELCOME to REAL CORP 2024, the 29th International Conference on Urban & Regional Development and Spatial Planning in the Information Society!

Since the beginning of industrialisation, the concentration of greenhouse gases in the atmosphere has been steadily increasing due to human influences. Currently, an increase of greenhouse gases in the atmosphere of almost 50 percent compared to the level of pre-industrialisation has been recorded. Without taking into account the increase in greenhouse gases in the atmosphere, the observed warming of the climate system cannot be explained. The problem of climate change is therefore caused by humanity itself and can therefore be counteracted by humanity itself.

It is, therefore, all the more important to take selective countermeasures wherever possible. If measures against climate change are combined with modern technologies, additional short-term effects can be achieved, such as an increase in the (urban) quality of life, a mitigation of traffic problems or savings through reduced resource consumption. These and other aspects can be achieved under the umbrella of the Smart City, and Mannheim has decided to become a Smart City and is on a successful way: as the first German city, Mannheim received the #EUMissionLabel as part of the "100 climate neutral and smart cities by 2030" programme by the EU Commission.

But what does this step mean for the citizens on the one hand, and for planning and administration on the other? Smart Cities use the potential of digital technologies and intelligent data networks to increase the quality of life simultaneously moving into the future in a resource-saving and efficient way.

Smart cities collect vast amounts of data, which can be used to inform policy making and city planning leading to more effective urban and regional governance. Also the economic aspect must be considered as Smart Cities can attract investments and businesses, creating job opportunities and stimulating economic growth. They can also foster innovation and entrepreneurship through technology hubs and incubators. This contributes to the development of services by delivering public services more efficiently, such as healthcare, education, and public safety. This enhances the overall well-being of residents and can contribute to social development.

Clustering promotes progress, and Mannheim has been leading the way in this area for some time. With the initiation of the Network Smart Production, Mannheim has created an innovation platform. Industry, research and solution providers are brought together and can initiate a variety of B2B and funded applied research projects. The combination of a strong production location and a strong green tech location makes Mannheim a hotspot of the green and smart industry. Last but not least,

Mannheim's Smart City movement is strongly supported by a university landscape with a network of co-operating universities with diverse and interdisciplinary research focus.

This year we brought together some 200 participants from more than 30 countries worldwide. The main goal of the REAL CORP conference series is to bring together leading experts in the field of spatial planning, geoinformation and related disciplines to exchange their knowledge, share their ideas, discuss current developments and get together for face to face networking leading to the development of new thoughts, partnerships and projects.

The success of the REAL CORP conferences is – clearly without doubt – the result of the efforts of participants, reviewers, and the conference organising team. We would like to acknowledge the Reviewer Team and Programme Committee members for their valueable voluntary help with the review process. Our thanks go to all participants and authors of the submitted papers as well. The programme of this year's conference contain around 100 scientific contributions; 63 of them were selected after a double-blind, double-stage (for both abstracts and full papers) peer-review process for publication and presentation at REAL CORP 2024. The non-reviewed papers were accepted by the programme committee after a double-blind abstract review.

Welcome to Mannheim! Have a great conference!

Manfred SCHRENK, Clemens BEYER & the REAL CORP Team

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A New Adaptation Strategy to Changing Local Climatic Conditions in Urban Areas? The Use of Leaf-Turning Tree Species

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1 ABSTRACT

The effects of climate change are especially felt in urban areas. Rising temperatures and changing precipitation patterns are challenging the maintenance of green oases in cities. However, urban trees are becoming increasingly important in mitigating these negative climatic effects, as they offer positive cooling potential to the surrounding area through the shading and evaporation capacity of the vegetation. At the same time, they are also susceptible to these weather extremes such as summer heat and drought, resulting in high surface runoff and low infiltration rates. This leads to the problem that native urban tree species, such as large-leaved lime (Tilia platyphyllos) and sycamore maple (Acer pseudoplatanus), are reaching the limits of their adaptability. In contrast, tree species native to south-eastern Europe are better equipped to cope with changing climatic conditions through various adaptations, such as leaf orientation in response to high levels of solar radiation. One potential adaptation strategy is the use of alternate-leaf tree species, which could mitigate the adverse effects of climate change in urban areas and improve the quality of life for residents. In particular, the silver lime (Tilia tomentosa) is becoming increasingly important in this context. It can turn the silvery underside of its leaves upwards when exposed to strong sunlight, leading to a change in the albedo and a possible reduction in surface temperatures in the crown area.

Keywords: city planning, adaption strategies, urban green, climate adaption, urban climate

2 INTRODUCTION

Urban areas have distinct climatic characteristics compared to undeveloped regions. Urban centres experience increased heating during hot periods and reduced cooling at night, which can adversely affect both plants and humans [Roloff 2013, pp. 168]. Many of the emerging risks of climate change are concentrated in urban areas [Kumar 2021, p. 1]. Central European cities are especially affected by the displacement of vegetation, increased storage of sensible heat fluxes, and additional anthropogenic heat emissions [Zhang et al. 2020, p. 1]. At the same time, the majority of the world's population lives in metropolitan areas. In 2022, 78 % of Germany´s population was urban, equivalent to approximately 69 million people [World Bank 2023]. Climate change is predicted to increase risks to people, assets, businesses, and ecosystems in cities. These risks include, for example, increased hazards from heat stress, air pollution storms, and heavy rainfall [Dodman et al. 2022, pp. 909]. The majority of direct weather-related deaths worldwide were attributed to storms (39 %), droughts (34 %), and floods (16 %) [Keim 2020, p. 268]. It is important to note that these risks will be exacerbated for those who lack access to essential infrastructure and services, or who live in high-risk areas [Dodman et al. 2022, pp. 909].

It is highly likely that global warming will exceed 1.5 °C to 2 °C in the 21st century unless significant reductions in carbon dioxide and other emissions are implemented in the next decades [Ara Begum et al. 2022, p. 129]. These rising temperatures can cause health problems such as heat stroke, heat exhaustion, and dehydration. The human body can adapt to heat to some extent, but the risks vary dramatically depending on exposure, location, and susceptibility [Ebi et al. 2021, p. 298]. A 1 °C increase in perceived temperature above city-specific thresholds temperatures is associated with a 3.12 % increase in mortality in Mediterranean cities (such as Athens, Rome, and Milan) and a 1.84 % increase in mortality in Northern European cities (such as Zurich, Stockholm, and Paris) [Baccini et al. 2008, pp. 716]. Extreme heat waves, consisting of several days of hot weather, have a greater impact on mortality than just elevated daily temperatures alone. This is because exceptionally high minimum temperatures prevent recovery from heat stress during the night, resulting in persistent heat stress throughout the day and night [Kenney et al. 2014, p. 1893].

Adaptation to changing local climate conditions is crucial for maintaining the quality of life of urban residents and strengthening the resilience of cities to the impacts of climate change. A resilient city has a high adaptive capacity, which enables it to adjust reactively and proactively to changing environmental conditions and to recover quickly from negative impacts [Birkmann et al. 2013, p. 18; Kuhlicke et al. 2024, p. 271].

There is growing recognition that "nature-based solutions" have the potential to mitigate the impacts of climate change, while also delaying further warming, promoting biodiversity, and securing ecosystem services. However, there are concerns about their reliability and cost-effectiveness when compared to engineered alternatives, as well as their ability to withstand climate change [Seddon et al. 2020, p. 1]. Nature-based solutions involve the use and enhancement of natural ecosystems to address societal problems [Cohen-Shacham et al. 2016, p. 2]. These interventions include a variety of strategies, such as the protection and management of natural and semi-natural ecosystems and the integration of green and blue infrastructure in cities. The concept is based on the premise that both healthy natural and managed ecosystems provide a wide range of services that are critical to human well-being, such as carbon storage, flood management, and clean air. Nature-based solutions range from maintaining or restoring diverse natural ecosystems to developing novel managed or hybrid "grey-green" techniques [Seddon et al. 2020, p. 2]. Hybrid "grey-green" strategies are systems that combine traditional grey infrastructure with nature-based solutions for a variety of applications, including disaster risk reduction and climate change adaptation. Examples of such approaches include rain gardens, green roofs, and street trees planted in pavement tree pits [Depietri & McPhearson 2017, pp. 101]. While urban greenery can provide numerous benefits to the urban climate and human well-being, it is important to acknowledge that prioritising urban greenery varies from person to person. Furthermore, aesthetic preferences are subjective and may change over time. For example, shading or a dark crown may be beneficial on hot summer days, but unfavourable in cool, humid summers [Roloff 2013, p. 29].

Urban trees improve the quality of life by filtering the air, providing moisture, and creating a pleasant urban microclimate. They also play a crucial role in adapting to climate change by protecting against the effects of heat and drought. In addition, they can contribute to biodiversity and perform essential functions for the urban climate and biodiversity by forming complex ecosystems [Roloff 2013, pp. 15-22]. However, the environment in which urban trees grow is very different from their natural habitat, which can affect their performance and lifespan [Breuste 2019, p. 151]. Urban trees often have a life expectancy of only 50 % of their potential age range, while street trees have a life expectancy of only 25 % [Roloff 2013, p. 8]. These aggravating conditions include small tree grates, soil compaction, reduced gas and water exchange, and a lack of rainwater due to sealing and pollutants in the immediate environment (such as road salt and car exhaust). This results in significantly shorter lifespans and lower performance, which are often in high demand [Breuste 2019, p. 151]. In addition, higher air temperatures due to urban heat islands, make trees in urban areas increasingly vulnerable to weather extremes, especially summer heat and drought. Native urban trees, such as the summer lime tree (Tilia platyphyllos) and sycamore maple (Acer pseudoplatanus), have been shown to approach their limits of adaptability. However, continental, non-native species are often characterised by greater stress tolerance, increased vitality, and longer foliage length [Böll et al. 2021, p. 3]. To continue to provide cities with the benefits of urban trees it is therefore essential to select tree species that are better adapted to changing climatic conditions and to protect and preserve these trees as an important adaptation measure to adapt to climate change [Roloff 2013, p. 168].

3 TILIA TOMENTOSA

Tilia tomentosa, also known as the silver lime in the United Kingdom and the silver linden in the United States, is a drought-tolerant and thermophilic tree species native to southeastern Europe. It naturally occurs in the Balkan Peninsula and north-western Turkey as well as in Hungary and Romania [Bartha 1995, p. 5; Heinrichs et al. 2021, p. 1; Kleber et al. 2022, pp. 41]. It has been part of horticultural cultivation since 1767 and has been used as a street tree for many years. It is specifically important for urban and green space planning because it tolerates heat, air, and drought better than native lime species. The silver lime tree was included in the "Urban Green 2021" project in 2009 because of its heat and drought tolerance and has proven to be particularly robust in the hot and dry location of Würzburg. Research conducted as part of the project shows that the silver lime maintains lower leaf temperatures during heat waves than the small-leaved lime

(Tilia cordata). This is probably due to its silver-haired leaves (refer to Fig. 1) and the ability to actively turn its leaves in hot weather (refer to Fig. 2). As a result, the silver lime tree is less likely to exceed critical temperature thresholds compared to the small-leaved lime tree [Schönfeld 2022, pp. 2-6]. Therefore, Tilia tomentosa is classified as highly suitable for drought tolerance and suitable for cold hardiness [Roloff 2013, pp. 176-182].

Figure 1: Photograph depicting the leaves of a silver lime tree located in Kaiserslautern, Buchenlochstraße, on 22 August 2023. The photograph shows the contrast between the dark green upper side and the light, silvery underside of the leaves [Geib 2023].

The flowers of the silver lime are grouped in pendulous inflorescences. The main axis of the inflorescence is partially united with a silvery-white, smooth-edged, and elongated subtending leaf. The individual flowers are almost white. It flowers in July and is pollinated by bees and other insects. Its fruits are nuts that grow in an inflorescence with a parchment-like support leaf. They are pointed and egg-shaped, ripen in September and October and are dispersed by the wind [Bachofer & Mayer 2021, p. 100]. It was previously assumed that the silver lime was responsible for the increased bumblebee mortality because its nectar was considered toxic to insects. However, recent research has disproven this theory. The actual cause of the widespread bumblebee mortality under silver lime trees is food competition among the insects [Koch & Stevenson 2017, p. 8; Roloff 2013, p. 159; Jacquemart et al. 2018, para. 3.3.2].

The leaves of the silver lime are initially covered with star-shaped hairs on the upper side but often become completely bare later [Binder 2015, p. 23]. The underside of the leaves has a dense layer of star-shaped hairs, giving them a silvery appearance, and sunken stomata [Böll et al. 2021, p. 5; Binder 2015, p. 23]. This hairy layer prevents aphid infestation and honeydew, while also protecting against heat and excessive evaporation [Roloff 2013, p. 159]. When exposed to extreme heat, the silver lime tree turns its leaves so that the lighter underside faces upwards, reflecting the incoming solar radiation. The change in albedo reduces the surface temperature of the canopy (refer to Fig. 2) as well as the air temperature under the canopy and around the trunk area [Henninger 2020, p. 76].

Figure 2: Thermal imaging camera images before rotation (left), during rotation (centre), and after rotation (right). High surface temperatures are represented by red-coloured areas and lower surface temperatures by blue areas [Henninger 2020, p. 76].

4 METHODS

This research project aims to investigate the use of leaf-turning tree species as a possible adaptation strategy to changing climatic conditions in urban areas. The focus will be on analysing the changing albedo and decreasing surface temperature at the canopy of the silver leaf and its potential impact on the immediate environment, particularly concerning its use as a roadside greenery [Geib & Henninger 2023, p. 43].

4.1 Study area

The measurements are carried out in the city of Kaiserslautern (49° 26‘ 36‘‘ N, 7° 46‘ 08‘‘ E), Rhineland-Palatinate, Germany. Kaiserslautern is a university and industrial city, with an urban area of about 140 km2. In particular, about 62 % of the area is covered by forest, which corresponds to 87 km2 [Geiger 2013, p. 54]. The city's average annual temperature is 10.2 °C, with air temperatures ranging from an average between 1.9 °C in January to 19.3 °C in July [Deutscher Wetterdienst 2023a]. The average annual temperature in Kaiserslautern has increased significantly by 2.0 K since the end of the 19th century, especially in recent decades [Stadtverwaltung Kaiserslautern 2019, p. 6]. Furthermore, Kaiserslautern has an annual precipitation of 764 mm, with the highest amount of 69 mm being recorded in May [Deutscher Wetterdienst 2023b].

4.2 Site and tree selection

The in-situ measurements are carried out at various locations throughout the city, all of which are roadside green spaces. Streets are selected based on tree species, stage of development phase, and the presence of a direct comparison tree (refer to Fig. 3).

According to the GALK list of street trees, there are differences in the suitability of different species of silver lime as street trees. Therefore, Tilia tomentosa ‘Brabant’ (well suited) and Tilia tomentosa (limited suitability) will be investigated to verify possible intraspecific differences [GALK 2024]. In addition, the influence of the development phase is considered in the measurements. As trees use different adaptation strategies depending on their life stage, the silver lime trees are divided into the phases of youth, maturity and old age. This makes it possible to determine the dominant leaf-turning ability within a particular age group [Geib & Henninger 2023, p. 44].

As the measurements are made in the street and not under laboratory conditions, a reference tree (of any species) and a silver lime tree should ideally be placed directly next to each other. This will allow a direct comparison of the values as the trees are in similar environments.

All studied silver lime trees surveyed are measured for their physical characteristics, including height, diameter at breast height, crown base height, and crown radius. The Department of Environmental Protection in Kaiserslautern, Germany, maintains a database containing information on all the silver lime trees in the city, including botanical name, trunk diameter (1.3 m a.g.l.), crown diameter, tree height, estimated age, vitality, stage of development, and traffic significance. This data is used to select and identify silver lime trees.

4.3 Meteorological selection criteria

The aim of this study is to investigate the impact of trees on the microclimate of street canyons during warm summer conditions and extreme heat, as this is when the cooling benefits of trees are most significant. To achieve this, the following meteorological conditions have been defined: data will only be recorded on summer days with little wind (≤ 1,5 m s-1), clear to almost clear skies (degree of cloud cover ≤ 1/8) and a temperature of at least 25 °C (refer to Fig. 3) [Geib & Henninger 2023, p. 44].

Figure 3: Overview of the objects and conditions of the investigation [Geib 2023].

4.4 Data collection

The surface temperature of the tree canopy is measured by using a thermal imaging camera (refer to Fig. 4). The study examines three specific perspectives of the tree canopy: the side facing the house façade, and the east and west sides of the tree canopy [Geib & Henninger 2023, p. 44]. These perspectives are chosen to capture potential temperature variations caused by solar radiation and prevailing winds. By analysing these different perspectives, it is possible to infer a possible correlation between the surface temperature of the tree crown and the building facade. However, it is important to note that it is not always possible to obtain measurements from all canopy perspectives. This may be due to several factors, such as private property restricting access, business premises being closed on weekends, or varying distances from the building facade. These limitations can affect the comprehensiveness of the data collected. Nevertheless, efforts are made to ensure consistency in data collection.

In addition, thermal images of the surrounding buildings are taken to observe any response of their facades due to reflected radiation from the leaf surfaces. This step is essential to understand how the thermal properties of the canopy can affect nearby structures and contributes to a comprehensive analysis of microclimatic effects. All photographs are taken from a fixed position at each site, perpendicular to the wall, providing a standardised approach. Care is taken to ensure that canopy foliage has little or no contact with the wall surface, which could affect temperature readings.

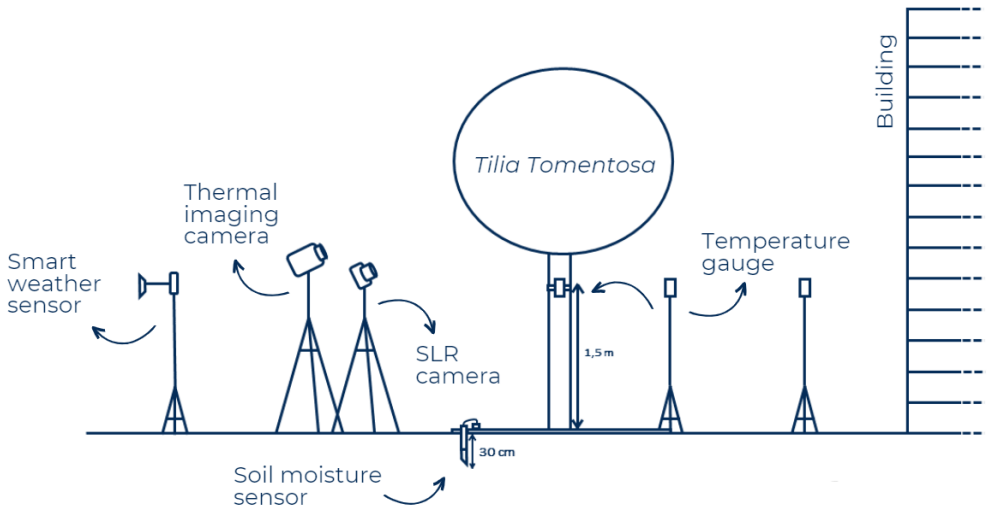

Figure 4: Outline of the experimental set-up; modified from [Geib & Henninger 2023, p. 44].

In addition to measuring the surface temperature of the tree canopy, three additional air temperature values are collected to analyse the effect of the crown temperature on the immediate environment. The first component measured is the air temperature just below the tree crown, at a height of 1.5 meters above ground level (refer to Fig. 4). This height is chosen because it is more representative of the human environment than the standard measurement height of 2 meters above ground [Souch & Souch 1993, p. 304]. During these measurements, the temperature sensor is protected from direct sunlight and placed in the shade to ensure accurate readings. Additionally, two further air temperature measurements are taken from the trunk of the tree towards the wall of the house (refer to Fig. 4). This approach aims to provide an accurate representation of the microclimatic effect in this particular area [Geib & Henninger 2023, p. 44]. These measurements will help to understand how the thermal behaviour of the tree affects its immediate surroundings, especially the building facade.

It may be beneficial to consider further environmental factors that can influence the surface temperature of the tree canopy. For example, weather conditions such as cloud cover, wind speed, and humidity can all affect the thermal behaviour of the trees. Incorporating these variables into the analysis could provide a more comprehensive understanding of the relationship between the tree canopy temperature and the building facade. Thus, the air temperature, air pressure, wind speed and direction, relative humidity, illuminance, and UV index are recorded at all locations during the measurement [Geib & Henninger 2023, p. 44].

To gain a full understanding of the impact of solar radiation, it is important to measure the temperature of the tree canopy at different times of the day. By collecting data during the peak hours of sunlight and in the

evening, valuable insights can be gained into how building orientation and shading affect the thermal behaviour of the trees. To achieve this, measurements are taken at specific times throughout the day: early morning (07:00-09:00 UTC+1), midday/early afternoon (12:00-15:00 UTC+1), and late afternoon/early evening (17:00-19:00 UTC+1). These times are chosen because the measurements will be taken in the presence of the researcher. To avoid overloading the body with heat and to meet human needs, a continuous measurement period is not used.

It is important to note that subsequent analyses only compare measurements within individual trees. This is due to the uniqueness of each measurement site and tree, and the impossibility of replicating exact weather conditions. Therefore, comparisons will be made within each tree to understand its thermal behaviour throughout the day.

In addition to the field measurements, laboratory tests will be carried out to determine the maximum absorption of different leaf surfaces of the silver lime tree and reference trees. This will be used as a benchmark for optimal absorption performance and will allow comparison with measurements taken at street level. This approach will provide a detailed understanding of how different factors, such as solar radiation, building orientation, and leaf surface characteristics, affect the thermal behaviour of trees in urban environments.

A soil moisture sensor is used to measure the water content of the soil surrounding each silver lime tree. The moisture level is determined daily by measuring vertically through the soil profile to a depth of 30 centimetres (refer to Fig. 4). The sensor is placed in a shaded area, furthest away from the main trunk, to minimise the effects of direct sunlight and ensure a representative location for water uptake. As urban trees are increasingly planted in small tree discs, the furthest distance from the main trunk is limited to the size of that particular area [Geib & Henninger 2023, p. 44].

Close-ups of the leaves in the canopy are also used to record the rate and duration of leaf rotation to classify the temporal dimension [Geib & Henninger 2023, p. 44].

Figure 5: Insights into the setup at one of the locations; Buchenlochstraße, Kaiserslautern on 11 August 2023 [Geib 2023].

4.5 Spatial analysis and microclimate simulation

ENVI-met is a powerful tool for modelling microclimates at fine spatial scales. It provides visualisation tools to explain spatial patterns. Integration with AI and GIS platforms merges simulated microclimate data with spatial information about the study region [Mayer et al. 2024, pp. 1]. The TreePass module provides a comprehensive analysis of microclimate conditions to promote optimal tree growth and sustainability. It considers factors such as wind, light, and mechanical forces that affect trees, providing valuable insights for landscape architects, urban planners, and arborists. This information facilitates informed decisions on tree selection, location and maintenance strategies, improving the health, stability, and longevity of urban green spaces [ENVI-met 2024].

This study analyses the climatic effects of silver lime trees at different sites in Kaiserslautern using the ENVI-met software. The software assesses potential microclimate changes within a street resulting from an

increase in the presence of silver lime trees or their exclusive planting. Furthermore, this study compares the climatic differences between a newly planted street with young silver lime trees and a street with middle-aged or older reference trees. The aim is to assess whether small silver lime trees have a greater cooling capacity than older comparator trees, which could be due to their ability to rotate leaves. With the help of the simulations, it can also be calculated how long it will take for newly planted silver lime trees to reach the same cooling capacity as the existing street trees. ENVI-met's research provides valuable insights into the impact of silver lime trees on local microclimates, contributing to a broader comprehensive understanding of their potential cooling effects in urban areas.

5 OUTLOOK

If the assessments indicate that the silver lime tree has a significant local or microclimatic impact on its immediate surroundings, recommendations for urban planning measures will be developed. These recommendations will be particularly useful in addressing the need for green or green-blue infrastructure in the context of urban redevelopment, with a focus on the use of public space, the selection of appropriate urban vegetation, and related design issues [Geib & Henninger 2023, p. 44]. In addition, these findings raise other issues such as financial considerations and the impact on the use of other tree species. Additionally, it is important to consider how trees and other vegetation interact with elements of the public realm and what measures can be taken to replace existing trees through replacement planting, even if this means accepting small saplings for an extended period. These issues are crucial for informing practical decisions in urban planning and landscape architecture, and highlight the importance of understanding the precise microclimatic impact of silver lime trees in shaping future urban environments. Although this study focuses on the silver lime tree for urban greening measures due to the specific research objectives and questions, extending the investigations to other tree species in future studies could help to gain a more comprehensive understanding of tree species selection in urban environments and possibly provide new insights into the ecological and economic impacts of different tree species. It is therefore recommended that further research is undertaken to explore the diversity of possible tree species for urban interventions and to make informed decisions.

The spatial arrangement of streets can significantly impact the relationship between green spaces and buildings, as it influences the area available for greening measures. In narrow or busy street areas, it can be difficult to find sufficient space to plant trees or create green strips. This can lead to an imbalance in the relationship between green spaces and buildings and limit the development of green structures. In addition, urban planning factors such as the alignment of the street, the density of the buildings, and the existing infrastructure play a crucial role [Ali-Toudert & Mayer 2006, pp. 751]. An unfavourable location of the street in terms of solar radiation, wind conditions or air quality may affect the suitability of certain tree species or greening measures. It is therefore important to consider the specific conditions of the street location in urban planning and greening projects to enable the effective integration of green spaces in urban areas and to ensure a balanced distribution of green structures. Furthermore, the integration of nature-based measures, such as increasing the size of tree grates, unsealing pavements and incorporating sponge city concepts into urban planning, can significantly enhance urban greening efforts and improve the resilience of cities to the impacts of climate change [Knapp & Dushkova 2023, pp. 187].

In addition, based on the results obtained near buildings, conclusions can be drawn about the usefulness of silver lime trees as roadside greenery. In particular, the assessment will consider whether the reduction in ambient temperature around the tree is effectively counteracted by the change in albedo. This assessment is important to understand the complex relationship between vegetation and built structures and to make informed decisions about the selection and placement of urban greenery to achieve desired climatic benefits while minimizing undesired outcomes. Incorporating these factors into urban planning and design processes is essential for creating sustainable and climate-resilient urban environments.

6 CONCLUSION

Cities play a crucial role in urban planning by influencing decisions that affect adaptation strategies. This includes setting standards for existing and new structures to increase their resilience to climate stressors and creating green and blue infrastructure to reduce the impact of extreme weather events. Municipalities are also responsible for developing plans to protect vulnerable populations and critical infrastructure during such

events. These activities are crucial to increasing urban resilience and protecting the long-term development of cities from the impacts of climate change.

Adapting to climate change is not only feasible but more cost-effective than doing nothing in the long run. Urban areas are specifically vulnerable to the impacts of climate change. However, implementing good adaptation techniques can significantly reduce these risks. Strategic tree planting is an important aspect of urban adaptation. This requires detailed planning and careful selection of tree species to avoid additional costs associated with poor species selection and to minimise any drawbacks. This includes assessing species-specific cooling effects, adaptability to local temperature conditions, and long-term maintenance requirements. This way, cities can optimise their investment in urban greening projects while increasing their resilience to the effects of climate change. In addition, the use of climate-resilient tree species can bring many benefits to the urban environment, including improved microclimate conditions, better water management, and higher air quality. Furthermore, the presence of climate-tolerant trees helps to increase habitat supply, reduce vulnerability through biodiversity, and improve the overall living environment.

To effectively adapt to climate change, it is important to link existing policies with climate-friendly objectives and to ensure that investments are resilient to climate impacts. This requires integrating adaptation measures into existing policies to ensure coherence and synergy while reducing the possibility of counterproductive actions. At the city level, adaptation measurements are supported by a comprehensive and multidisciplinary approach that encourages cooperation with neighbouring municipalities, regions, and member states.

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🏆 *reviewed paper*

An Approach to Investigate the Relationship between Spatial Configurational Pattern and Heritage Classification: Case study Alexandria City

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1 ABSTRACT

Heritage buildings are an important aspect of any city in terms of their capacity to provide cultural reference points. The significance of heritage buildings to a city is profound and encompasses a range of cultural, historical, economic, and social dimensions. These buildings represent the city's cultural identity, embodying architectural styles and design principles from specific historical periods. Preserving heritage buildings is essential for maintaining a connection between the past and the present, fostering a collective cultural memory that contributes to the city's overall identity. Preservation strategies entail different levels of physical intervention ranging from the most conservative strategy to the most transformative. Thus, preserving heritage buildings involves a careful approach that respects and safeguards their significant elements, ensuring the enhancement of their memory rather than compromising or losing it. The adaptive reuse strategy is an example of strategic initiatives aimed at preserving heritage buildings' significance while aligning their functions with contemporary needs. In Alexandria, heritage buildings serve as invaluable cultural assets that embody a city's heritage legacy. Defining the urban center requires a crucial examination of the interplay between urban spatial morphology and the functions of heritage buildings, posing a critical challenge to the survival of such buildings.

This paper aims to investigate the correlation between the spatial configurational patterns of the urban network and heritage buildings situated in the historical business district of Alexandria, a Mediterranean city in Egypt. This paper adopts a methodology based on examining the spatial configuration pattern using space syntax with different radii. Analytical methods within space syntax will be used to classify and arrange heritage buildings according to their spatial patterns providing a deeper understanding of their heritage attributes. The applied methodology will be employed within the heritage core of Alexandria. This study primarily concentrated on assessing key metrics of Space Syntax: integration and choice, which are considered crucial indicators of the efficiency of the urban fabric based on three radii: local 400m low intermediate800m, and high intermediate 2000. Moreover, connectivity measures and patchwork will be integral components within the framework of space syntax, serving as essential tools to analyze and understand spatial configurations in urban environments. The base map underwent on-site refinement before being imported into Depthmap for conversion into an operational spatial model.

The study's findings reveal well-defined and distinct heritage sets among the identified landmarks, determined by the integration and choice measures of space syntax, according to certain radii. This investigation can help in the understanding of conservation approaches. Heritage buildings sharing the same spatial features and within the same heritage set will be subjected to an adaptive reuse strategy, this will ensure seamless integration of their new functions. This approach ensures a cohesive and purposeful transformation that enhances the overall functionality and utility of a harmonious built environment.

Keywords: adaptive reuse, space syntax, function, heritage, spatial morphology

2 INTRODUCTION

A city's extensive urban heritage constitutes a distinctive asset. This heritage is characterized by a wealth of cultural relics and historical buildings, offering an authentic representation of traditional patterns and historical styles from various historical periods (Guo et al., 2020; Shin, 2010; Zhang and Han, 2022). Heritage districts, loaded with urban memories and exhibiting unique historical characteristics, hold considerable artistic, cultural, and economic value. They play a vital role in the sustainable development of cities (Jokilehto, 2002; Wang et al., 2018). However, the dynamic nature of cities, marked by continual

updates, expansions, and population growth, poses challenges for the preservation of urban heritage (Boussaa, 2018; Zeng et al., 2018).

Heritage buildings play a pivotal role in shaping the surrounding community and contributing to the overall quality of life. These structures serve as tangible links to the past, fostering a sense of identity, continuity, and cultural pride within the community. The physical presence of well-preserved heritage buildings often enhances the aesthetic appeal of the neighborhood, creating a unique atmosphere. Moreover, these buildings become focal points for community activities, events, and tourism, contributing to economic and social vitality. Heritage buildings foster a shared historical narrative and contribute to a heightened sense of place. As integral components of the urban fabric, heritage buildings not only enrich the cultural tapestry of a community but also have the potential to positively influence the well-being and satisfaction of its residents (Plevoets and Van Cleempoel 2012)

The field of urban heritage conservation has undergone a significant paradigm shift. In the mid-twentieth century. The prevailing focus was on the restoration of individual monuments, concentrating solely on the historical significance of individual buildings. This approach, however, failed to acknowledge the crucial role that entire historic districts play in safeguarding a city's cultural heritage. Recognizing this limitation, a more holistic approach emerged in the 21st century – the Historic Urban Landscape (HUL). This approach emphasizes safeguarding the entirety of a historic district, acknowledging the layering of historical significance and cultural values deposited over time by different communities. The HUL approach managed to preserve the heritage districts' cohesive character and functional vitality of the entire historical fabric of a district (Wang, 2012).

A critical aspect of urban heritage conservation involves carefully considering the modernization and restructuring of historic districts to achieve a harmonious integration with contemporary urban spatial configurations (Liu 2022) (Said, Aksah et al. 2013). Urban morphology prioritizes the analysis of the contextual urban fabric and the intricate interrelationships between its components, surpassing a focus on isolated monuments. This holistic approach is considered a powerful tool in the realm of urban conservation. Bill Hillier elaborates on this concept through the development of space syntax theory. Some scholars argue that integrating urban evolution with space syntax analysis elucidates the intricate transformations cities undergo over time. This theory employs spatial networks, represented by segment or axial maps, to depict the city as a socio-spatial construct. These maps enable statistical comparisons between various cities or different sections within a city. Space syntax delves into the spatial configurations and patterns within built environments, offering a unique lens through which to analyze the intricate relationships between buildings and the socio-spatial contexts they inhabit. Integration and choice values within these spatial networks reveal patterns of "natural movement," encompassing movement toward destinations, or "to-movement," as well as movement through the network, termed "through-movement." It emphasizes the importance of focusing on how spatial arrangements influence the development and ongoing vitality of the surrounding context within the context of both space and function. (Palaiologou and Griffiths 2019). This paper argues that spatial networks can provide a strong platform to effectively link urban heritage to other aspects of its city.

3 SPATIAL ANALYSIS IN THE CONTEXT OF HERITAGE STUDIES

The relationship between space and its cultural and historical dimensions extends to include assets, values, and interpretations of heritage. By analyzing spatial cultures based on unique local topological and geometric features, this approach offers numerical representations of distinct cultural aspects associated with specific locations. Moreover, the syntax of spatial descriptions and the syntax of cultural meaning are interconnected aspects that highlight the understanding of both physical spaces and their cultural values (Hillier and Hanson 1984). In research related to heritage, three distinct categories emerge: "Designed Urban Heritage," focusing on intentionally crafted monumental urban spaces; "Assigned Urban Heritage," centered on historical urban areas officially designated as heritage sites; and "Lived/Emergent Urban Heritage," exploring the cultural value of everyday urban spaces that have organically evolved.

Traditional heritage management, while meticulously defining historic area boundaries and their physical influence, often overlooks intangible elements like cultural shifts and economic impacts. Space syntax theory, conversely, offers a fresh perspective. It focuses on the interconnectedness of spaces and buildings. By considering the entire urban context as a connected system, this approach fosters a holistic understanding

of historical evolution. (Griffiths 2012). The syntax of spatial descriptions and the syntax of cultural meaning are interconnected aspects. When cities want to rejuvenate areas by focusing on their heritage, they need to find the right balance between preserving the past and making sure the development is sustainable for the future. This requires carefully examining how the heritage fits into the ongoing flow of changes in the city over time. It's about creating a harmony between preserving what's valuable from the past and shaping the urban environment for a sustainable future (Stubbs 2004)

This section explores new research directions aiming to establish a meaningful connection between spatial history and heritage. Inspired by Harvey's idea of "heritageisation as a process" (2001, p. 320), Griffiths aligns with Harvey in emphasizing collaborative connections across history, heritage, and spatial studies.

Space syntax is a spatial analysis tool, primarily concerned with examining the structural aspects of a place rather than its character. It focuses on the spatial configuration and organization of urban environments, particularly the street patterns found in historical maps. By conducting an analysis of street layouts and correlating the findings with the current distribution of significant heritage buildings, Space syntax offers valuable insights into the historical vitality of these urban centers compared to their present situation. Through this application, a deeper understanding of the factors that contributed to the prominence of these centers in the past is achieved (Van Nes 2014).

The space Syntax method offers several notable characteristics that contribute to its effectiveness as a research tool for heritage analysis. Firstly, it presents a clear, manageable, and realistic way to model spatial aspects of a heritage settlement. Secondly, it involves examining city elements as interconnected components of a larger system. Thirdly, it assigns numerical values to these elements, enabling both statistical analyses and visual comparisons within the system. Lastly, its calculations generate values that allow for meaningful comparisons across systems of different sizes (Kubat 1999).

The configuration of heritage syntactic cores influences various functional aspects like movement, interaction, and navigation across different scales of the city. Both the shape and function of these cores offer distinct possibilities for organizing and classifying heritage urban spaces. For instance, the shape and function of a syntactic core can impact how people move through and interact within a given area. Similarly, the span or coverage of these cores determines the reach of their influence, affecting not only immediate surroundings but also broader contexts within the city. This interplay between shape, span, and function highlights how spatial configuration plays a pivotal role in shaping heritage urban dynamics and functionalities (Shpuza 2009) (Karimi 2012).

Based on the literature reviewed above, the aim of this paper is to utilize a spatial network approach to analyze urban heritage within its surrounding urban context. By conceptualizing urban heritage as an interconnected system, this research seeks to integrate urban heritage considerations with other pertinent planning matters, consequently providing substantiated evidence to enhance planning processes and decision-making concerning urban conservation. The spatial network approach incorporates two distinct analytical components. Firstly, it involves a configurational analysis of the spatial networks within the city context. This analysis focuses on segment and axial models, Secondly, the approach employs an analysis of heritage networks. This analysis establishes connections between heritage data and the segment model, revealing the interrelationships between the city's spatial structure and its historical elements.

4 RESEARCH METHODS

The methodology employed in this research focuses on the preservation and management of cultural heritage, specifically targeting heritage buildings in Alexandria, Egypt. The study utilizes a structured approach encompassing three phases for the development and dissemination of heritage digitization. The First phase involves Spatial networks within the framework of space syntax theory are employed to identify the spatial attributes of the historic core and to examine heritage within its urban context. Space Syntax methodologies delve into the hierarchical structure of the street network within the heritage center. This includes the computation of integration and choice measures, such as axial lines and segment analysis, to gain insights into the spatial configuration and connectivity of the street network and to examine heritage within its urban context.

Second phase, heritage data are integrated with the spatial model to build heritage networks. This facilitates the examination of the spatial relationship between heritage assets, street integration, and choice levels. The

process involves identifying essential landmarks within the heritage center of Alexandria such as historical buildings, monuments, and cultural sites are precisely pinpointed. By analyzing how these heritage assets are distributed across the street network hierarchy and integrated streets, a heritage map is created, outlining defined heritage sets between the identified landmarks. The third phase entails the creation of "heritage sets" through the superposition of the network maps: the spatial networks and the heritage network Figure 1

1. Heritage network analysis

The process involves identifying essential landmarks within the heritage center of Alexandria such as historical buildings, monuments, and cultural sites are precisely pinpointed. Heritage data is then comprehensively integrated into a segment model, constructing heritage networks.

2. Spatial network analysis:

Spatial networks of the city, represented by segment maps indicating integration and choice, enable the visualization of the city's spatial configurations in numerical terms. Segment maps also reflect the city as a dual system with foreground and background networks and indicate movement patterns. Integration values indicate to-movement and choice values indicate through-movement. Hence, spatial networks of the city offer a framework for connecting urban heritage to its urban surroundings and for analyzing heritage within its urban context.

This research uses the Integration and Choice segment maps of Alexandria at R400m, R800m, and R2000m as spatial networks of the city, to analyze spatial characteristics of the historic core, heritage within its urban context, and the relationship between the top high Integration and choice segment lines and heritage.

3. Heritage sets established

Subsequently, after heritage networks are built, the heritage networks are analyzed to identify the most significant and high-ranked heritage segments within the network while emphasis is placed on prioritizing segments characterized by a dense concentration of heritage buildings to establish heritage sets. By comparing their spatial and movement patterns, the research establishes a link between these sets and their urban context. This provides a foundation for integrating heritage considerations into urban planning issues.

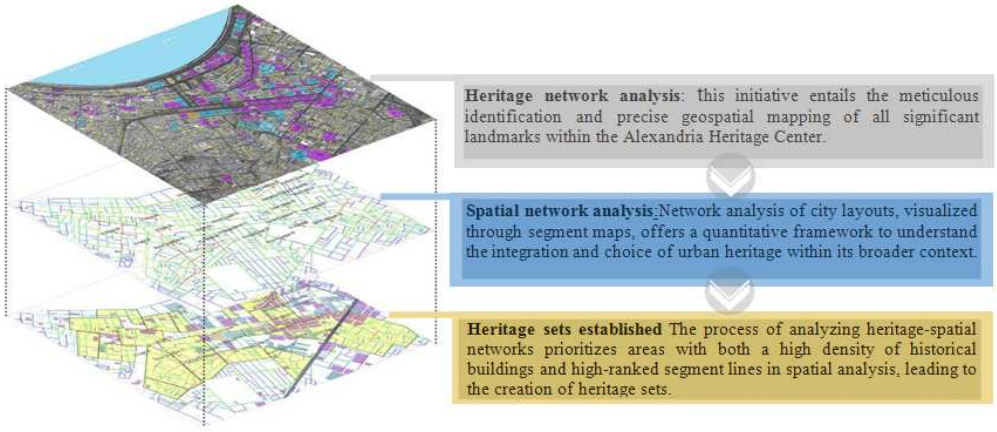


Figure 1: The adopted methodology for establishing heritage sets. Source: authors.

5 CASE STUDY: OVERVIEW OF ALEXANDRIA

The case study will employ the aforementioned methods of heritage data collection and mapping, alongside both spatial and heritage network analyses in Alexandria's historic core. The research site was purposefully selected due to the abundance of urban heritage assets within its boundaries. This particular area exemplifies the diachronic development of Alexandria, encompassing the city's origins and subsequent layers of historical accretion.

Alexandria, recognized for its rich history as one of the ancient cities globally, was established by Alexander the Great in 331 BCE and served as Egypt's capital for centuries. The city boasts a unique environmental blend, harmonizing the Mediterranean Sea with Lake Mariout, and seamlessly integrating agriculture with urban planning nearby. Alexandria features diverse historic buildings spanning various architectural styles.

Alexandria changed, transforming into a Ptolemaic city and becoming the largest in the Mediterranean basin. After the Turkish conquest in 1517, a new settlement emerged, characterized by houses, mosques, and small shops, mainly centered on the Turkish town. The declaration of Egypt as an autonomous state by Mohammed Ali and efforts to modernize attracted European migration in the late nineteenth century, introducing Western urban architecture and contributing to a renaissance under Mohammed Ali's rule (AbdelSalam 1995).

In the latter half of the 20th century, Alexandria underwent significant transformations influenced by political, economic, and social shifts, characterized by the departure of foreign nationals and an influx of rural migration, leading to a densely populated urban environment. These changes resulted in the deterioration of architectural heritage and the proliferation of concrete structures lacking aesthetic values. Political and economic shifts in the 1950s and 1960s, including the nationalization of European properties, prompted a mass departure of Europeans from Egypt, impacting the city's planned urban and architectural character. Existing buildings were repurposed for government use, leading to widespread urban fabric transformation through the demolition of older structures and the construction of new high-rises. The deterioration of built heritage escalated in the early 21st century, driven by changing demographics and a focus on short-term gains without considering the potential loss of cultural and aesthetic values. Unfortunately, the importance of preserving this architectural heritage for future generations was neglected, and preservation efforts faced minimal resistance (Heba, 2011).

5.1 Heritage Characteristics: Current heritage building listing in Alexandria

The initiative to conserve and list Alexandria's cosmopolitan heritage emerged with the 1982 comprehensive plan proposed by the government, later reviewed locally in alignment with city planning policies (Alexandria-Government, 1982; Dix, 1986). The survey conducted in 1982 resulted in the registration and listing of numerous buildings, diverse architectural styles, and entire streets and neighborhoods. This planning effort aimed to establish a significant historical connection between the contemporary city center and its rich historical background. The historical center outlined in the 1982 plan, representing the most recent transformations, is defined by the Cornish Road to the north, Safia Zaghloul Street to the east, Masjid el Attarin to the south, and Ahmed Oraby Square to the west.

In 1999, the Alexandria Preservation Trust (APT) revisited the 1980s survey, augmenting it with additional buildings of distinct styles (Alexandria Preservation Trust 1999). This survey followed the demolition of several registered buildings, either through successful lawsuits by owners in the Supreme Court or unauthorized demolitions that circumvented prevailing laws. Subsequently, conservation laws and building listings underwent progressive upgrades, culminating in the enactment of Law 144 in 2006. Building listings were consequently updated for the third time in 2007.

Under Law 144, the governor of Alexandria commissioned ALEX-MED to compile the Alexandria Heritage Catalogue, encompassing historic buildings, streets, districts, and artworks requiring protection. The resulting catalog, approved by the Egyptian prime minister in January 2008, adheres to five criteria for inclusion: possessing a unique architectural style, connections to historic figures or national history, representation of a historic period, or serving as a tourist attraction.

The listing categorized the heritage listings into three levels, regarding their significance, considering the national, city, or local classification. According to that classification 1135 buildings, across the different districts' conservation buildings were concentrated in Downtown Alexandria around the eastern harbor, represented in the Eastern and Central districts, which is a true reflection of the city's historic and urban fabric evolution. Downtown Alexandria acts as the Heritage node of the city emphasizing its urban significance (Alex-Med, 2007). The Downtown area represents around 80 percent of conservation buildings within the city as shown in the heritage building's map. The conservation buildings within this area represent the early and late expansion period influenced by the European community through the Central and Eastern districts, while the Al Gomrok district represents the Turkish-style conservation building within the city. The conservation catalog listed 38 conservation streets, where 36 of them were listed within downtown Alexandria emphasizing the heritage value of this part of the city (Reimer 1993).

Figure 2: The heritage map of Alexandria core showing the listed heritage buildings.Source: (Alex-Med, 2007)

5.2 Spatial characteristics

The historic core's spatial networks embody a distinct spatial culture. This generative structure fosters movement and co-presence, aligning perfectly with the heritage characteristics of the area.

5.2.1 Angular Segment Analysis

In the context of the case study, the angular segment analysis will be utilized to acquire measurements as segment maps will be employed instead of axial maps due to their higher accuracy and more widespread utilization. This choice is based on the recognition that segment maps offer enhanced precision and are more commonly employed in spatial analyses compared to axial maps. The analysis in this study will include both choice and integration, across multiple radii ranges. The diverse range of measurements obtained through this analysis is instrumental in revealing outcomes at various urban and spatial scales. The segment maps also make it possible to compare city areas with very different patterns of figures and ground or built

5.2.2 Angular Choice: Main Routes Through Cities and Regions

Choice represents the street segments that are highly chosen to be passed through as the shortest path The generated map is produced concerning the weight of angular connectivity for a critical angular path choice. This measure assesses the likelihood of roads being chosen for through movement. This study analysis employs different metric radii, starting with a local radius of 400m, providing insights into immediate, localized preferences. Subsequently, an intermediate radius of 800m is utilized, capturing choices that extend to a broader, intermediate scale. Finally, a higher intermediate radius of 2000m is implemented, offering a city-wide perspective on the preferred routes within the heritage areas. This multi-radius approach ensures a comprehensive examination of the choice measure, shedding light on the dynamic interplay between heritage spatial configurations and the through-movement preferences at various scales.

In the process of angular segment analysis within the case study, three specific scales are explored: the local scale at a radius of 400 meters, the low intermediate scale at a radius of 800 meters, and the high-intermediate scale at a radius of 2000 meters. While, the analysis at the local scale or neighborhood level, with a narrow local radius of 400 meters, offers a more detailed examination of immediate spatial preferences. In this context, the analysis identifies streets Al Attarin Mosque,Al Bab Al Akhdar Street, Al Dakkakin Street and France Street as the most preferred. Sets connecting these streets demonstrate the highest choice measure, indicating their significance at the local level shown in Figure 3a. The 800m radius scale highlights streets as Al Gazaar Street, Mahmoud Fahmy EL Nokrashi Street and Al Azhar Street as the most preferred. This means that these streets within their sets are consistently chosen for through-movement

reflecting their prominence and importance in the overall network at this intermediate scale as shown in Figure 3b.

While, the angular analysis of choice measure at a radius of 2000m indicates that, streets such as Ahmed Ourabi then El Nasr Street have the highest choice values for high-level intermediate through-movement on a city-wide scale. This implies that these specific roads are the most likely to be selected for movement from one point to another at a 2000m radius. In essence, on a high intermediate level, the sets associated with these streets are the most preferred ones for describing the through-movement from one location to another within the 2000m radius as displayed in Figure 3c

5.2.3 The Angular (Segment) Integration: The Location of Urban Cores

The angular segment integration shows the accessibility of a street segment in relation to all other street segments in an urban system in terms of direction changes. In this study, different metric radii are applied to unveil diverse "to-movement" potentials across various scale levels. A segment map colored using integration values generally shows the most integrated spaces in red to the most segregated spaces in blue. The most integrated set of spaces in the segment structure represents the syntactical cores of the urban area

To achieve this, Angular Segment Integration is performed at a local radius of 400m, a low intermediate radius of 800m, and a high intermediate radius of 2000 meters. Firstly, at the local scale (radius 400 meters) of angular integration segment analysis a more detailed and fine-grained understanding of the local network of streets is achieved for example streets such as Al Attarin Mosque StreetAl Bab Al Akhdar Street,Mahmoud Mostafa Assal Street,and Haret AL set AL Nayma Street and El Midan Street are highlighted. This analysis identifies clear local heritage sets, shaped by the previous streets that demonstrate high local integration. This reflects the pivotal role of these streets in shaping the overall urban spatial structure, emphasizing their significance in the local context Figure 4a. Secondly, the analysis recognizes the streets that are most integral to movement and connectivity at this intermediate scale of 800m exemplified by streets Adib Bek Ashak Street,Ahmed Ourabi Street, Salah Salem Street, Al Attarin mosque,El Nasr Street and Al Gazaar Street. Consequently, these streets are grouped into distinct heritage sets, characterized by intermediate integration values as shown in Figure 4b.

Finally, a high metric radius of 2000 meters is used for the angular segment integration analysis. The main streets with the highest values for the angular (segment) integration analysis are highlighted revealing the to-movement potentials on a high intermediate scale for example Ahmed Ourabi, El Nasr Street, El Midan Sreet, and Sidi El Metwalli Street. These main streets establish defined sets within the heritage area, referred to as the highest integrated heritage sets also they serve as primary axes as shown in Figure 4c.

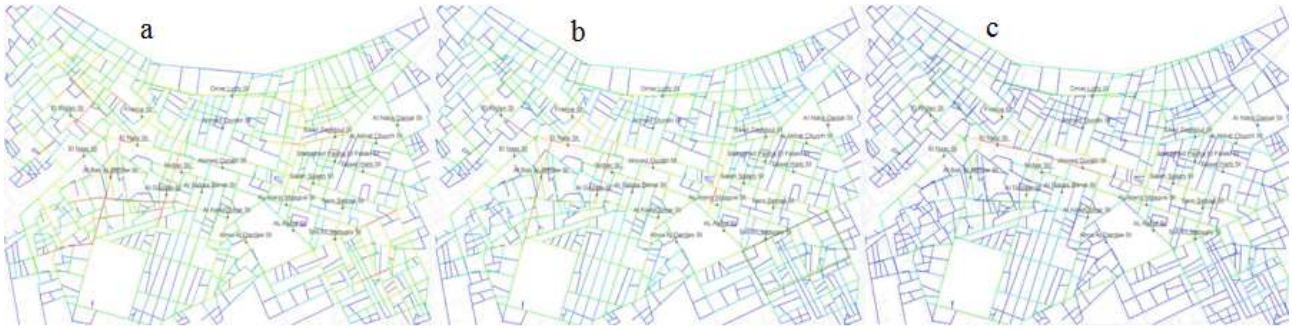


Figure 3: angular segment analysis-choice measure (a)400m raduis-(b) 800m raduis-(c) 2000m raduis. Source: authors.

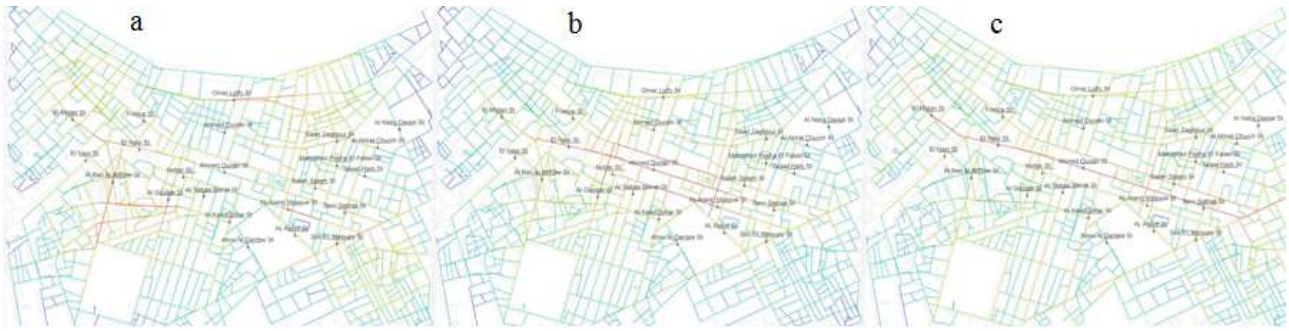


Figure 4: angular segment analysis-integration measure (a)400m radius-(b) 800m radius-(c) 2000m radius. Source: authors.

This methodology involves assessing the spatial configuration, connectivity, and layout of buildings within a given heritage context. The synthesis of Space Syntax analysis and heritage analysis results enhances the classification process by establishing a comprehensive, multidimensional framework. This framework serves as a crucial tool for categorizing and comprehending the organizational, relational, and contextual significance of heritage structures. Through the strategic integration of Space Syntax attributes and heritage analysis, the primary aim is to refine the classification of heritage buildings and systematically arrange them into cohesive sets, considering both spatial and historical dimensions. This unified methodology significantly augments the depth and precision of assessing heritage buildings

In this phase, each of the above maps was overlaid on the heritage map to find out how the heritage buildings represented in the map were correlated with the results of space syntax analysis, focusing on angular choice and angular integration maps. This entails how the cultural and historical layers represented in the heritage analysis map align or interact with their spatial configurations. It reveals areas where cultural significance and high spatial connectivity converge, providing valuable insights into how historical and cultural elements influence the city's spatial structure and generate defined heritage sets.

5.3 Heritage networks and Heritage sets construction

Urban heritage represents the cumulative layering of human cultures across space and time, serving as a historical record of a city's growth. This analysis investigates the distribution of heritage elements within the contemporary spatial network of the historic core.

5.3.1 Space syntax analysis (In the angular choice analysis)

Each set will be given a number and the initial letter of the specified radius Local-Intermediate-Global. For example, set number 1 in the Local radius will be named 1L, set 1 in the Intermediate radius will be named 1I, and set 1 in the Greater Intermediate radius will be named 1G

a. Space syntax analysis (In the angular choice analysis conducted at a scale of 400 meters local scale):

The identified sets play a crucial role in enabling seamless thorough movement across the city and contain the streets with the highest choice values and colored in dark red, for example, set 1L-6L. Next are the sets with fewer choice values and colored in light red as sets 7L-10L as shown in Figure 5a

b. The heritage Analysis:

Upon superimposing the heritage map, it becomes apparent that Set 1L comprises the most extensive assemblage of heritage buildings, then sets 4L and 10L have fewer heritage buildings leaving the rest of the sets with the least number of heritage buildings as shown in Figure 5a.

c. Space Syntax Analysis: (In the angular choice analysis conducted at a scale of 800 meters intermediate scale):

Some sets as 1I,2I, 3I, and 4I include streets of high values of angular choice colored in dark green while sets 5I-10I sets with streets of low choice values which are colored in light green as shown in Figure 5b

d.The heritage Analysis

Upon superimposing the heritage map, it becomes apparent that sets 1I, and 6I comprise the most extensive assemblage of heritage buildings, while sets 4I,7I,8I, and 9I comprise less amount of heritage buildings. The remaining sets within this radius exhibit minimal to no presence of heritage buildings as shown in Figure 5b

e. Space Syntax Analysis: (In the angular choice analysis conducted at a scale of 2000 meters greater intermediate scale):

Sets such as 1G incorporate streets characterized by high values of angular choice in a greater intermediate scale. While sets 2G-9G include streets with lower values of angular choice as shown in Figure 5c

f. The Heritage Analysis

Upon superimposing the heritage map, it becomes apparent that Set 1G,6G,7G, and 8G comprise the most extensive assemblage of heritage buildings as presented in Figure 5c

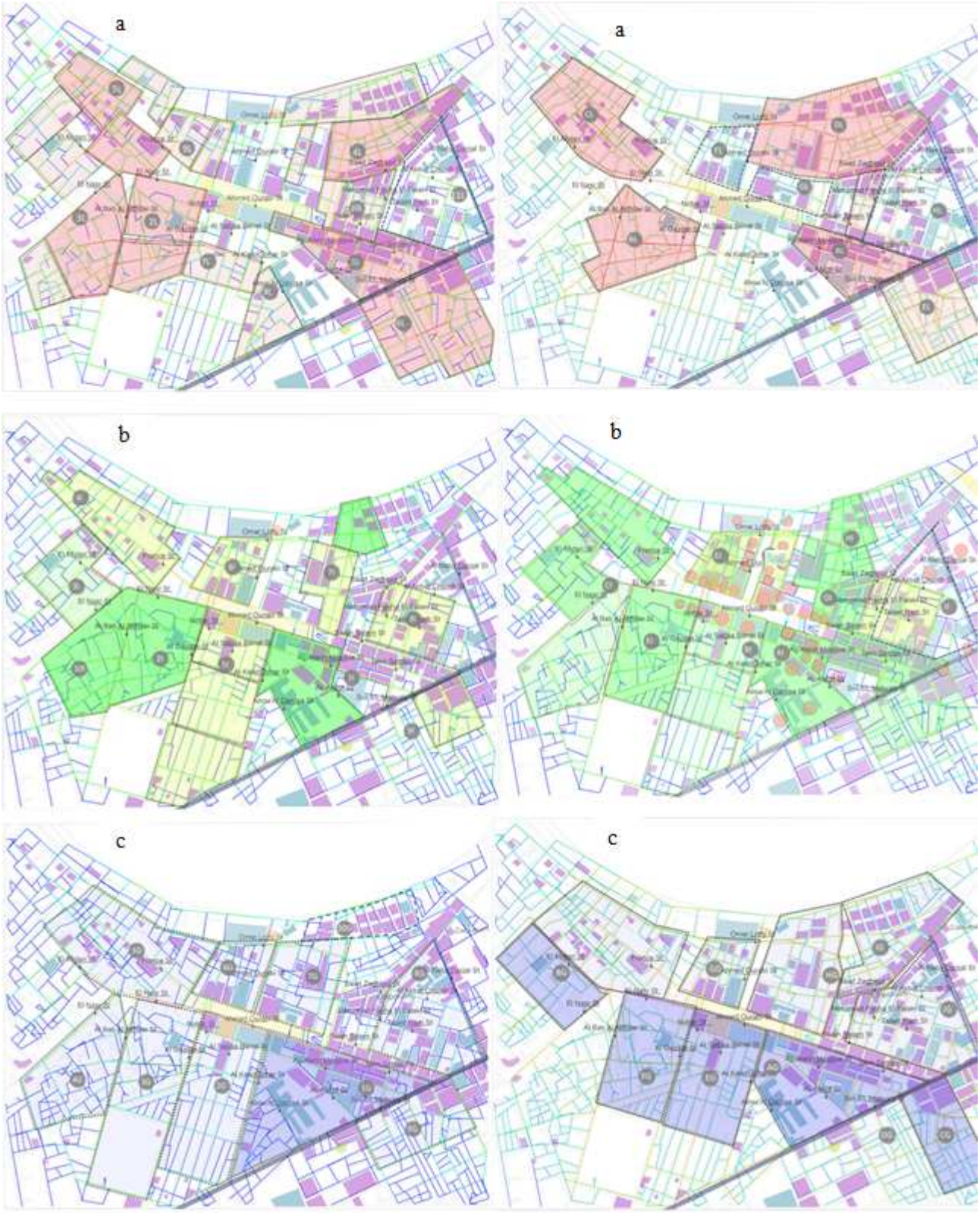


Figure 5 (left): Angular segment analysis overlaid on Heritage map-choice measure (a)400m radius-(b)800m radius-(c)2000m radius. Source: authors. Figure 6 (right): Angular segment analysis overlaid on Heritage map-integration measure (a) 400 m radius, (b)800 m radius, (c) 2000m radius. Source: authors.

5.3.2 Space syntax analysis (In the angular integration analysis)

Each set will be given an alphabetical letter and the initial letter according to the specified radius Local-Intermediate-Global. For example, set number A in the Local radius will be named AL, set B in the Intermediate radius will be named BI, and set C in the Greater intermediate radius will be named CG.

a.Space syntax analysis (In the angular integration analysis conducted at a scale of 400 meters local scale):

Sets that incorporate streets with high integration values at a local scale are characterized by a strong level of connectivity and accessibility between various locations at this level such sets are AL, BL, CL, and DL these sets are colored in dark red. Set EG demonstrates lower integration values, attributed to the streets within it having the least movement values as shown in Figure 6a.

b. The heritage Analysis

Upon superimposing the heritage map, it becomes apparent that Set AL comprises the most extensive assemblage of heritage buildings. While set DL and EL with fewer heritage buildings. Then sets BL and CG have the least number of heritage buildings as shown in Figure 6a.

c. Space syntax analysis (In the angular integration analysis conducted at a scale of 800 meters intermediate scale):

The presence of streets with high integration values at an intermediate scale is indicative of a well-connected urban environment such sets are for example AI, BI, CI DI, and EI and are colored in dark green. While sets FI, GI, and HI exhibit streets characterized by low integration values, consequently resulting in an overall low integration value for these respective sets as shown in Figure 6b.

d. The heritage Analysis

Upon superimposing the heritage map, it becomes apparent that Set AI, BI, DI, FI, and GI comprise the most extensive assemblage of heritage buildings. While set CI, EI, and HI have the least number of heritage buildings as presented in Figure 6b

e. Space syntax analysis (In the angular integration analysis conducted at a scale of 2000m greater intermediate scale):

The streets with high integration link the set to external areas and potentially to other sets, amplifying the set's accessibility to distant locations, services, and amenities exemplified by sets AG, BG, and CG and colored in dark blue. Sets DG, EG, FG, GG, HG, IG, and JG are characterized by streets with lower integration values at 2000m radius, consequently resulting in the sets having the minimum integration values at this scale as shown in Figure 6c.

f. The Heritage Analysis

Upon superimposing the heritage map, it becomes apparent that Set AG, BG, CG, GG, HG, IG, and JG comprises the most extensive assemblage of heritage buildings. While set DG, EG, and FG have the least number of heritage buildings as presented in Figure 6c.

5.4 Connectivity measure

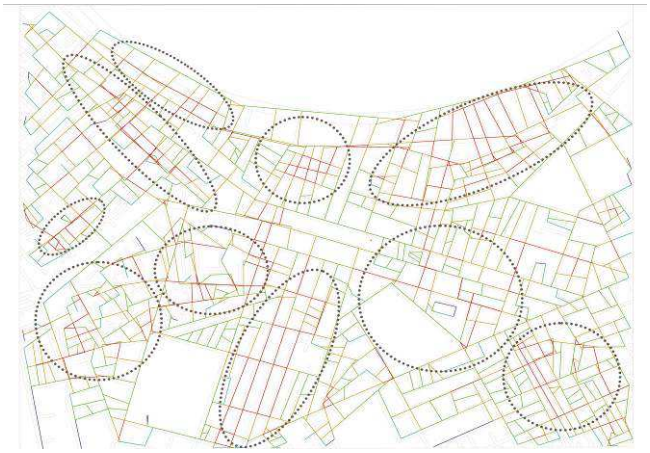
This map visually represents patches and areas with high connectivity values, depicted in red. The red coloring signifies that these specific areas or building blocks are highly connected or fall within a syntactic depth of 1. This outcome aids in delineating connected and cohesive heritage sets closely linked within the urban fabric, offering insights into spatial relationships and heritage groupings within a relatively short distance as shown in Figure 7

5.5 Patchwork

In this methodology applied in the case study, identifying patchwork involves calculating the mean depth metric within a 200-radius. This reveals local areas with unique spatial characteristics, showcasing how the interactions of streets and pathways influence block shapes and sizes. These patches signify metrically integrated areas distinguished by their distinct local connectivity as shown in Figure 8

6 RESULTS

Heritage Set AL, AI, and AG sets encompass a large number of heritage buildings and also have an increased propensity to draw movement at the local, global, and intermediate scales in the choice and integration angular analysis. The heightened value attributed to this heritage ensemble is a result of its evaluation in both the heritage, where its historical significance is assessed, and its spatial analysis while overlapping across different radii which considers its impact on the city's physical structure as illustrated in



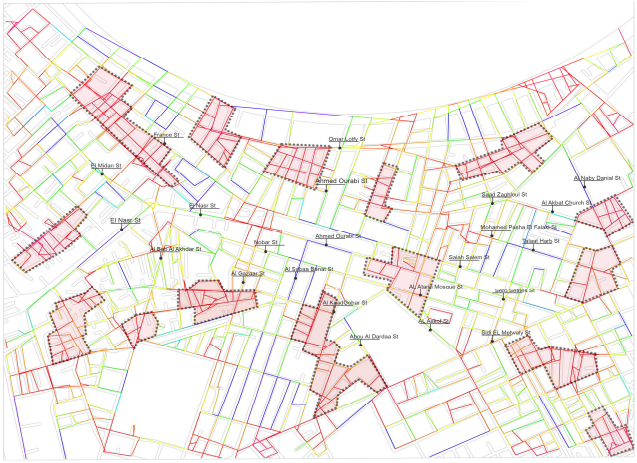


Figure 7 (left): Connectivity map showing heritage sets according to syntactic depth. Source: authors. Figure 8 (right): Patchwork map showing heritage sets according to block size. Source: authors.

The findings indicate that, despite the prominence of some sets in terms of preferred movement and spatial centrality according to space syntax analysis, they may not comprise as many formally designated heritage buildings for example sets 2L,3L,3I,4I,3G,4G in the angular choice measure and BL, FI, FG in the angular integration measure. This underscores a nuanced interplay between perceived significance in urban movement patterns and the official recognition of heritage status, emphasizing the need to consider diverse criteria when evaluating the historical and cultural fabric of an urban area Figure 9 Figure 10

The results highlight a discernible pattern where most historical buildings are positioned along streets with substantial to movement and through movement. Nevertheless, it is crucial to acknowledge that specific historical sites diverge from this trend. While the streets may not be as attractive or central within the specified radius, their abundance of listed heritage buildings underscores their crucial role in preserving and representing the city's historical and cultural identity. This suggests a nuanced dynamic where the formal recognition of heritage value may not always align with the spatial preferences within specific radii, highlighting the importance of considering diverse criteria in the evaluation of urban spaces such as sets 11L,6I,8I, 10G in the angular choice measure and FL, GL, HL, II in the angular integration measure.

Figure 9 (left): The identified heritage sets superimposed generating a choice map across different radii. Source: authors. Figure 10 (right): The identified heritage sets superimposed generating an integration map across different radii. Source: authors.

7 CONCLUSION

In conclusion, through a series of analyses, this research yields critical insights pertaining to the characterization of heritage elements, the spatial configurations, heritage networks, and the formation of heritage sets. Heritage buildings play a crucial role in linking the present to the past, offering narratives of architectural evolution, societal development, and significant historical events. Their contribution to a city's unique character and aesthetic appeal creates a sense of continuity amidst urban transformation.

The field of urban conservation has increasingly recognized the importance of integrating urban heritage into the cityscape. This research contributes to this focus by introducing a new spatial network approach. This approach not only facilitates the connection of urban heritage to its surrounding city but also enables the exploration of urban heritage as a fully interconnected system. The analysis focuses on the spatial layout and connectivity of a heritage site, aiming to understand its levels of integration and choice. The spatial network approach takes spatial networks from space syntax theory as a platform to connect urban heritage to its city. Moreover, the research identified the spatial characteristics of the historic core. The spatial network approach also links heritage data to the segment model to build heritage networks. In essence, this study aims to systematically group heritage buildings sharing the same spatial characteristics into clearly defined sets. These heritage sets hold significance in the realm of urban planning and development. This information becomes pivotal in making informed decisions about integrating heritage structures into the evolving urban landscape. Achieving a harmonious balance between heritage preservation and contemporary functionality

The assessment and measurements of the Downtown Alexandria heritage area and spatial configuration contribute to the comprehensive framework for spatial-cultural assessment in downtown Alexandria. This phase of the research is expected to enhance the understanding of the evolution of heritage sets, providing valuable insights for the preservation and sustainable development of historic urban areas.

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Analysis of Digital Technological Applications in Public Transportation Systems Ticketing and Communications: Reviews of Singapore, Sydney, Cape Town and Lagos Experiences

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1 ABSTRACT

The world's urban population has seen an unprecedented growth in the last few years and will continue to soar rapidly in the coming years. Public transportation systems need to be equipped to handle this influx of people into cities. Digital technology applications have been adopted in public transportation systems by many cities around the world to help optimise trips. However, the various digital technology applications and experiences in developed and developing cities remain understudied.. The study uses qualitative data in the form of content analysis and case study analysis through the investigation of four cities, Singapore, Sydney, Cape Town and Lagos, and their implementations of digital technologies – ticketing and communication in public transportation systems. Through the analysis of two developing cities in Africa and two developed cities in Asia and Australia, the lessons of cities' peculiar experiences provide valuable insight around contactless payments such as mobile ticketing and smart cards and smart applications in the form of mobile applications which provide trip details. Finally, the study draws on each case by highlighting the uniqueness of lessons learnt when implementing digital technologies to improve public transportation systems. Future research into user experiences of digital technology applications in public transportation is necessary in providing deeper understanding of their effectiveness.

Keywords: digital technology, public transport, smart cards, ticketing, smart applications

2 INTRODUCTION

The world's urban population has seen an unprecedented growth in the last few years and will continue to soar rapidly in the coming years. By the year 2050, the world's urban population is expected to rise to 68%. This will further issues of traffic congestion, decreased parking availability and an increase in pollution. Therefore, there is a need for improved public transport systems which are equipped to handle this influx of people into cities (Bieler et al. 2022). Digital technology applications have become extremely popular in public transport systems, with smart cards and smartphones replacing the use of paper tickets as a method of payment (Durand et al. 2023). Information communication and technologies (ICT) have transformed public tranapsort systems. The most popular form of ICT is the smartphone. Majority of public transport users around the world have access to smartphones and public transport applications have proven to be very useful in disseminating public transport information through mobile applications and collecting user data through these very applications (Strenitzerova and Stalmachova 2021).

The paper starts by analysing literature on digital technology applications in public transportation systems, focusing on ticketing and communication, it then goes on to review the four different cases and finally concludes by drawing on the lessons learnt from each case.

3 LITERATURE REVIEW

3.1 Smart ticketing

Ticketing of public transport around the world are now dominated by Automated Fare Collection (AFC) systems (Li et al. 2018). These systems include contactless payments such as smart cards, smart watch payments, mobile payments (debit/credit cards), scanning QR codes and fare readers that read different methods of payment (Sydney.com 2023). Smart card data proves useful in determining different user trip characteristics, making it easier to improve on existing and new public transport plans. However, smart card

data cannot provide other important details such as trip purpose, user satisfaction and so forth (Mohamed et al. 2016).

3.2 Communication

Mobile usage in public transport is becoming a popular option for not only paying fares and purchasing tickets via mobile apps but to also receive information pertinent to trips from these applications as well (Bieler et al. 2022). Information and Communication Technologies (ICT) provide useful information to users of public transport systems, in the form of trip planning, mode options and links between different modes to make effective and efficient decisions. However, there are limitations to having ICTs in public transport. Three key limitations are users access to the technologies, user's technological skill levels and just how pertinent and reliable the information provided by the technology is (Ryseck 2019).

4 METHODOLOGY

The study collected qualitative data in the form of case study analysis. Four cities were selected based on digital technology applications within the public transport system. The four cities selected were Singapore, Sydney, Cape Town and Lagos, as the cities represent two developed cities in Asia and Australia and two developing cities in Africa respectively. Data was sourced from Google Scholar, Scopus, Web of Science as it allowed for more access to information pertinent to the study. The data was further broken down into digital technology applications implemented in the form of ticketing and communication for each city.

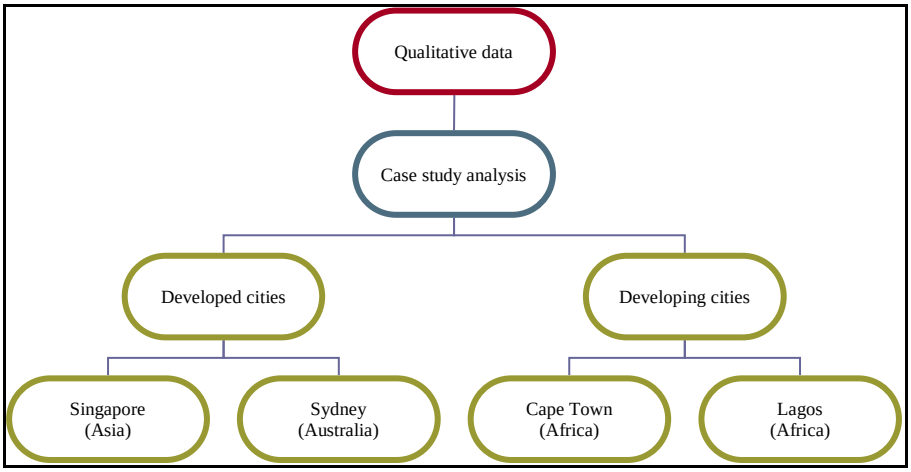

Figure 1: Breakdown of data collection and analysis (Source: Authors 2023)

The last stage of analysis was the creation of a table of the unique lessons learnt by each city's experiences of implementing digital technologies in public transport systems. Above (Figure 1) is a breakdown of the stages between data collection and analysis.

5 RESULTS AND DISCUSSION

The results below analyse four different cities, Singapore, Sydney, Cape Town and Lagos. Each city is broken down into the method of ticketing and communication used in the city's public transport system. The approach to the cities public transport planning is also explored to provide a context for the decisions made by the cities.

5.1 Singapore

Singapore occupies an area of 719,1km² and has an extremely high population density ratio, resulting in an increasing demand for public transport. Therefore, Singapore looks to mitigate the negative effects of this increased demand through the implementation of more sustainable public transport policies. The three core elements of Singapore's public transport policies lie with decreasing the use of private motor vehicles, increasing shared mobility and public transport and finally improving the integration of transport and land use planning. The policies further focus on smartness, inclusiveness and greenness. Singapore achieves sustainable public transport through efficient public transport systems that promote economic developments, strict private vehicle regulations coupled with environmentally friendly modes of transport which contribute to environmental sustainability and lastly, imposing high vehicles taxes and affordable public transport fares

encourages social equity (Diao 2019; Haque et al. 2013 and Singapore Academy of Corporate Management 2024).

Users of public transport in Singapore can make use of two modes of payment, one in the form of a contactless smart card and the other is mobile payment approaches (Wolniak and Grebski 2023). Singapore's electronic ticketing system is the EZ-Link card (Zhu 2020). The EZ-Link card was first introduced in Singapore in April 2002. The card allows public transport users to pay for different modes of transport creating a more integrated system as well as an easy and efficient payment method (Wolniak and Grebski 2023). It is important to note that the EZ-Link card can also be used for other payments such as some retail purchases, tolls and parking. The fares of the card are dependent on the distance travelled, the age demographic of users giving a cheaper rate to seniors, students and children (Chakirov and Erath 2011).

Figure 2: EZ-Link card reader (Source: EZ-Link 2023)

The EZ-Link card is so widely used that it was found that between 1 August 2013 and 31 October 2013, 97% of public transport users had used the EZ-Link card for payment of trips and only 3% of users paid using cash (Liu et al. 2019). In 2022, EZ-Link card readers were able to read Mastercard and EZ-Link's collaboration called Pay by Wallet through loading the card on users' mobile devices which were able to make contactless payments for public transport trips and other e-commerce payments (Ang 2022). EZ-Link smart card data was found to be a useful source for research. A study found that data provided by the smart card combined with data from StarHub mobile geolocation would be able to determine and create popular feeder routes and main public transit lines and can explain the variables affecting route choice (Poonawala et al. 2016).

The EZ-Link card is linked to an EZ-Link mobile application which allows users to real-time top-up their EZ-Link cards, making tracking funds and rewards easier and reducing queues at ticketing machines (EZ-Link 2023).

Figure 3: EZ-Link Mobile app (Source: EZ-Link 2024)

Singapore has another mobile application called 'SG bike' that allows you to locate bicycles real-time through the application or physically, once located at a docking station, scan the QR code on the bicycle with the application and it automatically unlocks the bicycle for use. Bicycles can also be unlocked with a membership card (Wolniak and Grebski 2023).

5.2 Sydney

Covering 12368,7km² of land, Australian public transport planning has been centred around land use planning which is a facet of metropolitan-based strategic plans. However, in the last two decades, public input around the processes and policies which govern the city have taken the forefront in planning and is referred to as 'consensus-based planning'. Australian cities, specifically Sydney, seek to integrate land use and transport planning to allow for the improvement in accessibility of residents. The financing and urgency of transport plans are not discussed with the public which tends to lead to financing and first preference going to high-profile road projects and not to public transport projects (Legacy, Curtis and Scheurer 2017 and City of Sydney 2023).

Sydney has adopted an electronic ticketing system in the form of a smartcard for public transport. The smartcard is called the Opal card, which replaced the previously used paper tickets. The Opal card was introduced between 2013 and 2014 in a step-by-step method (Ellison et al. 2017). The Opal card provides an integrated transport system as the card can be used on different public transport modes, which are; bus, train, light rail and ferry (Qu 2022). Though the Opal card itself provides contactless payments, Opal card readers also allow contactless payments from Visa debit and credit cards, Mastercards and American Express cards (Sydney.com 2023). There are six different Opal cards; adult, child/youth, gold, concession, school and free opal cards. Each card has a different has a different fare with the adult Opal card paying the highest fares.

Figure 4: Sydney's Opal card for public transport payments (Source: Poposki 2019)

A study conducted on the travel behaviour of public transport users based on the introduction of the Opal card system found that the new system was much simpler in terms of fare structures than the previous paper ticketing system and encouraged more car to train switches. Users of the Opal card were also more likely to use public transport on weekends as the new fare structure allows for unlimited trips capped at $50 a week for adults (Ellison et al. 2017). The Opal card itself is useful in collecting data on travel behaviour as it was able to track the patterns of seniors in order to analyse their preferences of public transport use (Harada, Birtchnell and Du 2023).

In 2015, it was recorded that 79% of Australians were using smartphones (Tompson 2015). Sydney has two mobile applications available to public transport users. The first application is called 'TripView' and provides timetables for different public transport modes.

A study conducted in Sydney found that the TripView app is popular among those with intellectual disabilities and therefore helps improve social inclusion in public transport (Danker 2023). The second application is called 'Next Station' and not only provides timetables of different public transport modes but also includes real-time vehicle position as well as service notifications that can be set to various languages (Sydney.com 2023).

Figure 5: TripView App summary of trip view (Source: TripView 2024)

5.3 Cape Town

The population of Cape Town was at an estimated 3.78 million in 2018 with an area of 2455km². Cape Town is the most traffic-congested city in South Africa, having both low- and high-income areas (Smith 2021 and New World Encyclopedia 2024). The history of Apartheid planning has greatly influenced the city of Cape Town and its spatial characteristics. Cape Town has a growing issue of urban sprawl which has since worsened by public-led investments. This means that residents have to travel further distances (to and from work, education, entertainment, and so forth), having major implications on the cost of trips increasing. The planning of public transport in Cape Town is handled by the Transport and urban Development Authority (TDA) agency. The TDA aims to achieve the implementation of a high quality and inexpensive public transport services. The city is guided by policy in the form of the National Land Transport Act from 2009 which requires Cape Town to have a Comprehensive Integrated Transport Plan (CITP) to guide public transport planning (Allansson and Kajander 2017).

The MyCiti bus rapid transit (BRT) uses a smart card payment method called the MyConnect card. The MyConnect card was made available free of charge to South African users in 2013, however, a R30 fee to pre-load Mover points was required to attain the card (MyCiti 2013). In order to use the BRT, users are required to possess a MyConnect card. There are no other payment methods available other than the MyConnect card on the BRT. However, the MyConnect card is only available for payment on MyCiti BRTs and no other form of public transport in Cape Town. The MyConnect can now be purchased for R35 from MyCiti booths or from retailers that sell the card. One use cards can also be purchased for R30 and airport route cards for R100. All MyConnect cards require a pre-load Mover points before travelling. The fares of the MyConnect card are dependent on the distance and whether the trip is peak or off-peak. The smartcard comes with different fare packages available for regular and occasional users, with regular users attaining discounts. Users are able to tell when their cards need to be topped up by the validator turning yellow and beeping twice (less than R20 available) and red beeping five times when payment is unsuccessful (no funds available). Users are charged a penalty for unsuccessful payments (Smith 2021).

The MyConnect card has been a useful tool in research projects which analyse travel data that include routes of users through the process of route node insertion to generate various network scenarios to optimise MyCiti BRT routes as there have been financial losses incurred by the service and a lack of funding to help solve these issues (Mzengereza 2021).

Figure 6: MyConnect card being tapped aboard MyCiti BRT (Source: MyCiti 2024)

Cape Town has three active ICT mobile applications that provide public transport users with schedules which are essential to trip planning. The three apps are 'GoMetro app', 'TCT app' and the 'iOSMyCiti app' which is not an official one.

Figure 7: Transport for Cape Town (TCT) app (Source: Sustainable Energy Africa 2017)

The city had two other apps called 'Transport Hero' and 'Public Transport App' to provide a similar service, however, due to little marketing and a low number of downloads, both applications were removed from the Android and iOS app stores (Ryseck 2019 and Ryseck 2022).

5.4 Lagos

Lagos has an area of 3345km² and is the highest populated city in Africa, with projections for 2100 being between 61 and 100 million inhabitants. Therefore, the city experiences the most traffic congestion in Africa. This increase in population means that there will be an increased demand for transportation (Paul and McSharry 2021 and Britannica 2024). In 1999, in conjunction with the newly appointed government, the World Bank introduced the Lagos Urban Transport Project which aimed at introducing a BRT, water transport, cable car and rail services. The Lagos Area Metropolitan Transport Authority (LAMATA) was then established through the Lagos State Ministry of Transport. Lagos has over 100 agencies of local, state and federal government which all would act in their own powers in making transport planning decisions, therefore, the introduction of LAMATA provided strategic goals that assisted agencies of government to work towards to (Klopp, Harber and Quarshie 2019).

Lagos has had two methods of paying for public transport, the Lagos connect card and Cowry. In 2015, Lagos launched their first BRT service called the Metro Bus. Along with the launch of the Metro Bus was the installation of a Card Validator and a Lagos Connect Card. The Lagos Connect Card could be tapped when entering and exiting the bus in order to get a 20 naira discount on any trip. At the time of the launch, it

was reported that not all buses had active card validators, many of the terminal points did not have card recharging services, passengers were being overcharged on trips and validators being switched off by drivers as paper tickets made more money (Popoola 2015).

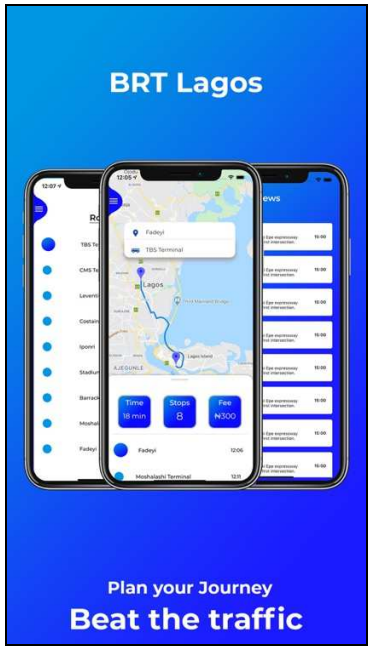

Figure 9: BRT Lagos app (Source: AppAdvice 2024)

Within the Cowry payment system, there are two forms of payment. First is the Cowry card which can be tapped (using NFC technology) upon entering and exiting the public transport mode. The Cowry card can be used on all transport modes such as ferry, BRT buses, and the First Mile and Last Mile (FMLM) Scheme, however, the BlueLine railway is still in the integration process. The Cowry app is the second form of payment, users can scan the app generated QR code at the readers. Users can top up their Cowry cards through the Cowry app wallet by a service agent or self-service validator at the relevant terminals (Cowry 2024). Use of the Cowry Card commenced in February 2021. A Cowry Card costs 200 naira (for a paper card) and 400 naira (for a plastic card). Card balances are displayed on the validator post payment to alert users on their balances (Joshua 2021). It seems that the current Cowry payment system has replaced the Lagos Connect Card system. Another mobile app would be the Lagos BRT app which provides real-time locations of BRT buses which are sent to central intelligence and transforms the GPS details to bus arrival and departure times for users. The app also provides users with other buses available close to their BRT stops (Amiegbebhor and Popoola 2021).

6 LESSONS LEARNT

Each city has had unique experiences with smart ticketing and communication. Fig. 10 shows the lessons learnt by each city. The lessons can be noted by other cities looking to implement such services.

7 CONCLUSION

The world's urban population continues to grow, making the need for efficient public transport systems extremely important. Both African cities, though both being some of the most developed developing cities in Africa faced challenges with smart ticketing and smart communication systems. However, these two African cities implemented alternative systems in response to previous challenges which proved that implementing such technologies in Africa requires a trial and error process which allows for tailor-made solutions that may not be applicable in developed cities. All cities allow for the use of smart card payments across different modes of transport except Cape Town which leaves room for creating a more integrated public transport system, thereby increasing mobility. However, Cape Town has spatial expansion restrictions in terms of the mountains and waterfront, Sydney has a large harbour, a series of waterways and challenging topography in some parts. Lagos has a similar situation being located on a strip of land between the Atlantic Ocean and a lagoon. Singapore also has spatial restrictions being an island, this means that public transport needs to be implemented strategically in all of these cities as they each have unqiue spatial challenges. One instance

where the African cities proved more user friendly would be the balance warnings promting users to top up which are not seen in the Singapore and Sydney systems. The implementation of the two systems improves convenience, optimisation, efficiency, accessibility and user experiences. The study found that the introduction of digital technology applications was not without its challenges but overall positively improved public transport systems not only for users but for transportation planning as well.

City	Lessons learnt
Singapore	The strict private vehicle regulations and high vehicle taxes coupled with environmentally friendly modes of transport and low fare public transport reduces private vehicle use. Two modes of payment (smart card and mobile) makes it easier for users to pay. EZ-Link card can be used to pay for various modes of transport and other small retail payments aiding in public transport integration. Fare structures generated on distance travelled coupled with other factors helps users attain fare discounts. EZ-Link data was able to determine and provide popular feeder routes for users. EZ-Link app made for easier EZ-Link top-ups reducing ticketing queues. 'SG bike' provides non-motorised transport to users at anytime through the scanning of a QR code or membership card.
Sydney	Financing of public transport projects not being discussed with the public leads to finances being used rather on high-profile road projects. Opal card readers not only allow Opal card payments but other mobile and credit and debit card payments, which creates efficiency during payments. Opal cards can be used to pay for multiple modes of public transport creating an integrated public transport system. Studies show that the new card system fare structure was easier for user to understand and increased car to train switches. Fare capping encouraged more weekend trips. TripView app provides timetables of different public transport modes. TripView aids in social inclusion. 'Next Station' app also provides timetables, real-time vehicle positioning and service notifications making it convenient for users.
Cape Town	The spatial form of Cape Town (urban sprawl) makes public transport planning difficult. The MyConnect Card can only be used for payments on MyCiti buses which does not promote public transport integration. No other methods of payment are accepted on the MyCiti BRT making it inconvenient for users. Regular users get higher discounts making public transport more affordable for everyday use. Warnings for low balances alerts users to top up before next trip and penalties for unsuccessful payments encourages top ups. MyConnect card data assisted in route optimisation of the BRT. Three different mobile apps for public transport schedules helps user communication. Low marketing on public transport apps leads to low use and eventual discontinuation of the apps.
Lagos	The creation of LAMATA helped effectively plan public transport systems. Use of the Lagos Connect Card ensured a discount encouraging smart card use. Various issues around inactive card validators, lack of recharging services and overcharging trips with the Lagos Connect Card led to the introduction of a new system called Cowry. Cowry can be used to pay for different transport modes promoting public transport integration. Cowry card and Cowry app serves as payment methods for public transport which is convenient for users. Balance alerts make it easier for users to know when to top up cards. Lagos BRT app provides real-time location information which makes bus arrival and departure times readily available to users. Lagos BRT app furthers convenience through providing users with other buses available close to their BRT stops.

Figure 10: Lessons learnt from Singapore, Sydney, Cape Town and Lagos (Source: Authors 2024)

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🏆 *reviewed paper*

Assessment of Residential Electricity Consumption and Renewable Energy Self-Sufficiency – a Case Study of Tainan, Taiwan

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1 ABSTRACT

Significant carbon dioxide emissions contribute to global issues such as rising temperatures and climate change impacts, which have emerged as a major and urgent global concern. As a result, numerous countries have committed to cutting down the emission of carbon dioxide to achieve low carbon and net zero emissions targets. As we know human activities such as transportation, construction, and electricity consumption significantly contribute to carbon emissions, and they are all in need of energy. Hence, it's important for every country to use clean energy to transform from low carbon to net zero emissions.

The transformation to renewable energy sources, particularly solar energy, has become a global imperative to combat climate change. However, in Taiwan, despite favorable conditions for solar energy development, there are challenges regarding the policy direction and spatial planning of PV (photovoltaics) installations. The current focus on ground-mounted PV, primarily in rural areas, has raised concerns about land use, environmental impact, and social equity. As a result, there is a pressing need to prioritize PV development in built-up areas to minimize conflicts with green resources and ensure sustainable land use, so the potential of rooftop PV is vital to built-up areas. This study uses Tainan, Taiwan, as a case study area, and the objective is to forecast electricity consumption in the residential and commercial sectors, evaluate the potential for rooftop PV development, and assess the feasibility of achieving renewable energy self-sufficiency in built-up areas. It also examines the electricity consumption patterns and rooftop PV generation potential in different urbanization contexts, emphasizing the need for tailored policies and regulations to promote fair and just renewable energy development.

The research highlights the importance of managing land resources judiciously and implementing policies that prioritize PV deployment in urban and rural built environments. In conclusion, the study underscores the urgency of addressing the spatial, environmental, and social implications of PV development in Taiwan to achieve sustainable energy transition goals. The findings are intended to provide a reference for integrating low-carbon principles into urban management plans. Furthermore, employing growth management as a tool for urban energy management is vital to ensure that renewable energy development adheres to rational processes and standards while protecting environmental resources.

Keywords: Residential Electricity Consumption, Renewable Energy Self-sufficiency, Rooftop Photovoltaic, Low Carbon City, Solar Energy

2 INTRODUCTION

After the Industrial Revolution, the widespread burning of fossil fuels led to significant carbon dioxide emissions, exacerbating global issues such as rising temperatures. The resulting climate change, directly caused by carbon emissions, has become a major and urgent global concern. Consequently, many countries have committed to achieving low-carbon and net-zero emission goals. To transform from traditional, non-renewable energy sources like coal to renewable energy sources and eventually achieve complete reliance on renewable energy for electricity generation, clear policy directions are essential. Moreover, due to the finite nature of land resources, these policies must be effectively implemented in spatial contexts.

The availability of land resources, building conditions, and people's lifestyles, all are influenced by different geographic environments and levels of urban development. They are crucial factors affecting the direction and types of renewable energy development. Therefore, clear spatial planning and layout play important roles in energy transition. Guiding the development of renewable energy fairly and justly is a crucial issue that all countries must address.

Taiwan is in a subtropical climate, so in the development of various renewable energy sources, we have high potential and conditions for installing PV. Therefore, solar energy development is one of Taiwan's primary goals in its energy transition policy. However, due to the lack of clarity in policies and locations, the current situation of solar energy development in Taiwan mainly focuses on large-scale ground-mounted PV and concentrates in rural areas. As a result, the PV encroaches upon agricultural and forestry land, leading to landscape destruction and other issues.

However, the proportion of solar energy development in the built environment, where humans live and reside, is relatively low. Therefore, it is evident that Taiwan faces issues of disorder and conflicts with green resources in solar energy development, which need to be urgently addressed and resolved.

2.1 The justice in the development of PV

2.1.1 The importance of managing the land resources

From the perspective of Nature-based Solutions(NbS) and land ethics, environmental resources should be valued and protected more because the land available to each country is limited, especially agricultural land, fish ponds, or forests, which are natural resources. If the land is converted, it may lose its original fertility, so the best approach is to minimize the impact on environmental resources. In the development of solar energy, PV should avoid being installed on land that provides environmental resources. Large-scale installation of PV on agricultural land or fish ponds not only severely damages rural landscapes but also raises concerns about whether the materials and cleaning processes of the PV may pollute the land. A more serious issue is that this PV may encroach on the production space of agriculture and fisheries, potentially leading to issues with the country's food production space and security.

Therefore, if PV could be installed as much as possible in urban or rural built-up areas, exhausting the electricity generation capacity of built environments and newly developed areas, and only then moving on to adopting agrivoltaic farm, fishery, and electricity symbiosis, or converting agricultural land. As a result, it is crucial to establish the correct solar energy development policies, so it can ensure the sustainability of the land and fair development of renewable energy.

2.1.2 The policies of PV and current development issues in Taiwan

Taiwan is actively promoting the transition to renewable energy with the global goal of achieving net zero emissions. It has set a target that by 2025, 20% of Taiwan’s total electricity generation will come from renewable sources, with a total installed capacity target of 29 GW. Given Taiwan’s favorable climate conditions, there is a strong emphasis on the deployment of PV, with a target capacity of 20 GW for PV and 5.6 GW for offshore wind power. Within the PV capacity target of 20 GW, 8 GW is allocated for rooftop PV and 12 GW for ground-mounted PV.

According to government planning objectives, Taiwan aims to achieve a capacity of 14 GW by 2023, with approximately 11.66 GW already installed as of October 2023. The capacity of rooftop PV has increased from 1.14 GW in 2016 to 7.33 GW in 2023. Future efforts will focus on installing PV on agricultural facilities, public buildings, school campuses, industrial rooftops, and community rooftops. On the other hand, ground-mounted PV capacity has increased from 0.078 GW in 2016 to 4.33 GW in 2023. The government aims to prioritize projects with societal consensus and no environmental or ecological disputes.

While the capacity of rooftop PV is relatively close to the target compared to ground-mounted PV, there is still a need to install approximately 7.67 GW of ground-mounted PV to meet the 2025 goals. However, the lack of long-term and substantive targets, as well as unclear planning principles and locations, raises significant concerns about potential impacts on vulnerable communities or land resources in the future.

Tainan City is one of the southern cities in Taiwan, which has been actively installing PV and has the highest installed capacity of PV in Taiwan, approximately 2.39 GW. However, many of these installations are observed to be large-scale PV set up on fishponds and agricultural land (Fig. 1). Despite government efforts to address threats to ecology or communities from fishery and electricity symbiosis projects through regulations and stakeholder engagement, these measures are seen as reactive rather than proactive. Additionally, the lack of clear long-term development goals and spatial planning in Tainan has led to the over-installation of solar panels in some areas, prompting residents to protest and demand a more proactive and positive response from the government regarding PV development. (Fig. 2)

In Taiwan's pursuit of energy transition, decarbonization, and sustainability, focusing solely on achieving the total installed capacity of PV without considering broader issues of land use and equity has resulted in conflicts with green resources. Thus, it underscores the importance of prioritizing the development of PV in built-up environments and the need for a comprehensive and prioritized approach to PV development. Taiwan has a similar area and population to the Netherlands, but the Netherlands' national vision plan, which emphasizes diverse development approaches based on the limited land area, thereby minimizing environmental impacts. Utilizing existing buildings in urban areas as sites for PV generation not only avoids unfair impacts on vulnerable areas or environmental resources but also enhances land use efficiency to ensure the sustainability of land resources. Moreover, integrating rooftop PV with energy storage technology and smart grids can change the traditional unidirectional power supply, helping urban areas have more stable power and reducing the risks of unstable renewable energy supply and transmission losses.

Fig. 1 (left): Ground–mounted PV in Taiwan (source: China Daily News). Fig. 2 (right): People protest excessive development of ground–mounted PV (source: Qigu Dist. Supervisory Optoelectronics Youth Alliance Facebook).

2.2 Electricity consumption and rooftop PV in built-up areas

Taking into account the summarized issues from the previous discussion, it is evident that the development of solar PV in built-up areas will be an important topic for exploration. Therefore, there should be efforts to identify the maximum potential for PV generation in built-up areas and explore the energy self-sufficiency achievable through PV generation under actual electricity consumption scenarios. This information can serve as a reference for subsequent policy formulation regarding PV development.

Currently, in built-up areas, Taiwan primarily focuses on rooftop PV, utilizing the roofs of buildings as space for solar panel installations to avoid direct land disturbance. This approach also creates opportunities for individuals to generate and sell electricity using solar panels, thereby promoting economic benefits and creating new job opportunities. However, compared to abroad where various types of buildings are gradually equipped with solar panels, Taiwan's regulations for rooftop PV only mandate certain scale buildings to install a certain proportion of solar panels.

To ensure that the development of renewable energy aligns more closely with principles of fairness and justice, there should be greater encouragement for the installation of rooftop PV in built-up areas. Therefore, this research aims to explore electricity self-sufficiency in built-up areas.

2.2.1 The degree of urbanization causes differences in electricity consumption and PV generation potential

Analyzing the overall electricity usage in a country can be broadly categorized into domestic usage and industrial usage. Domestic usage includes residential and commercial usage. Industrial usage includes primary industries and manufacturing. From preliminary analysis, it is evident that domestic usage is more universal and consistent compared to industrial usage. Industrial usage varies significantly based on the industry type and scale, making it less predictable and requiring regional power regulation to achieve balance. On the other hand, domestic usage is influenced by population density and development scale, making it relatively predictable. In urban areas, electricity usage is generally higher due to denser populations and diverse activities, resulting in more tall buildings and compact distribution (Fig. 3). Conversely, rural areas have lower population density, less diverse activities, and scattered, low buildings (Fig. 4), leading to lower electricity usage compared to urban areas.

Regarding the PV generation potential, built-up areas also vary in their suitability for generation due to differences in characteristics. For instance, urban areas with many tall and densely packed buildings may

have reduced potential for rooftop PV installation due to shading issues. Additionally, older buildings may have limitations on installing rooftop solar panels. In contrast, rural areas with more dispersed buildings and available land may have a higher potential for PV installation. As a result, considering regional differences in electricity usage and PV generation potential, statistical analysis and forecasting of both supply and demand sides are necessary to effectively promote PV development. This information can inform tailored policies and regulations to promote fair and just renewable energy development.

Fig. 3 (left): Urban area landscape in Taiwan (source: ETtoday News). Fig. 4 (right): Rural area landscape in Taiwan (source: taiwanhot).

2.2.2 The policies of rooftop PV and prospect in Taiwan and Tainan

Countries like Canada, Japan, and Germany have enacted laws to encourage and promote rooftop PV. For instance, in 2009, Toronto, Canada, introduced Chapter 492 of the Toronto Municipal Code, known as the Green Roofs. This law mandates that new buildings, new development zones, and residential projects with a total floor area exceeding 2,000 square meters constructed after 2010 must utilize 20-60% of rooftop space for greenery or solar panels. Similarly, Berlin, Germany, implemented the Berlin Solar Law in 2021, requiring new, expanded, or renovated buildings with a footprint exceeding 50 square meters to install solar panels covering at least 30% of the rooftop's net area.

In Taiwan, some Non-Governmental Organizations advocate for the principle of "urban electricity from urban areas" to promote regional development equity (Fig. 5). They propose incorporating rooftop PV into the law to prevent extensive solar panel coverage of environmental resources and excessive concentration in rural areas. Therefore, promoting the self-sufficiency of energy in residential and commercial areas within built-up areas is a key goal for Taiwan's future. However, in the subsequent legislative proposals, the Legislative Yuan stipulates that buildings with an area of 1,000 square meters or more, whether new, expanded, or renovated, must install 1 kW of solar power for every 20 square meters. This approach primarily targets large-scale PV, unlike Germany's law, which includes smaller residential buildings.

Fig. 5 (left): People advocate inclusion of rooftop PV in regulations (source: Citizen of the Earth, Taiwan.). Fig. 6 (right): Community rooftop PV in Taiwan (source: Yahoo News).

Taiwan is currently implementing the "Green Roof All-Participation" program for small-scale buildings like residences, aiming to realize the concept of a citizen power plant by encouraging rooftop solar adoption. In Taiwan's current system, after building owners install solar panels, the electricity generated is not for their own building's use. Instead, the government guarantees to purchase green energy at a higher price, providing a certain incentive. As a result, regardless of whether the building owners are the ones using electricity for

the actual building, it is beneficial to install PV as long as time and environmental conditions permit. However, single-building initiatives may result in energy inefficiencies or low economic benefits due to their small scale, leading to reduced interest among the public. Therefore, future policy and regulatory frameworks should emphasize community-level renewable energy systems planning for entire neighborhoods or communities to enhance flexibility in energy supply and demand (Fig. 6). Additionally, policymakers should incentivize the comprehensive renewal of older communities to promote the widespread adoption of rooftop solar in built-up areas.

3 METHODOLOGY

This study selects Tainan City as the empirical research base site, which has the highest installed PV capacity in Taiwan (Fig. 8). Tainan, located in an area with abundant sunlight, is an excellent location for PV development. Geographically, Tainan's terrain is higher in the east and lower in the west, leading to a natural tendency for people to reside in the flatlands to the west (Fig. 9). As a result, urbanization levels radiate outward from the city center on the southwest side, causing uneven population distribution spatially.

However, current data indicates that PV development in Tainan primarily occurs in rural areas on agricultural land and fish ponds. Some solar panels are situated very close to habitats of important wildlife species, resulting in changes to their habitats and potential inconveniences for residents. The current PV development in Tainan does not prioritize rooftop PV installations, highlighting the need to confirm whether rooftop PV development in built-up areas can meet the electricity demand of residential and commercial sectors. It is also need to analyze the feasibility of achieving energy self-sufficiency through rooftop PV in areas with different levels of urbanization. Future efforts will focus on formulating fair regulations to ensure the development of renewable energy aligns with principles of justice.

Therefore, this study will be divided into three parts. The first part involves analyzing electricity consumption patterns, focusing on residential and small-scale commercial buildings in built-up areas to assess whether electricity usage differs across areas with varying degrees of urbanization. The second part explores the PV generation potential in built-up areas. Considering factors like building age, form, and density, the study will simulate different scenarios to understand the PV generation potential of rooftops. The third part calculates the self-sufficiency rate of electricity by comparing the power supply and demand in areas with different levels of urbanization. These results will serve as references for formulating future renewable energy development strategies based on regional characteristics and conditions.

(1) Calculation of Actual Electricity Demand

To understand the electricity consumption trends in a specific area, this study will analyze residential and commercial electricity sales data collected by the Taiwan Power Company over the past five years (2018-2022). In addition to analyzing electricity consumption trends in various areas, the data will be inputted into GIS systems for spatial analysis.

(2) Simulation of PV Generation Potential on Different Building Rooftops

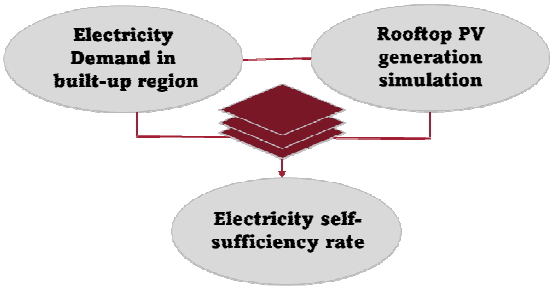


Fig. 7: Schematic diagram of research methods

To further understand how urbanization levels affect electricity consumption, this study will select three administrative districts—West Central District, Qigu District, and Longqi District—as the main research areas based on their urbanization levels. Given that the lifespan of PV is approximately 20 years and buildings typically have a lifespan of 50 years, different scenarios will be simulated to calculate the PV generation potential of rooftops. The first scenario assumes that buildings older than 30 years will not be considered, and only relatively new buildings (30 years old or less) will have solar panels installed. The

second scenario assumes that both new and old buildings will have rooftop PV installed, with older buildings also being retrofitted with PV. Similarly, solar panels will cover 50% of the projected area of the building in both scenarios to analyze the potential generation capacity in built-up areas.

(3) Calculation of Electricity Self-Sufficiency Rate

By combining the results of the first two steps, the electricity consumption and potential supply of electricity in a specific area can be determined. These results will then be used to analyze the electricity self-sufficiency rate in different regions.

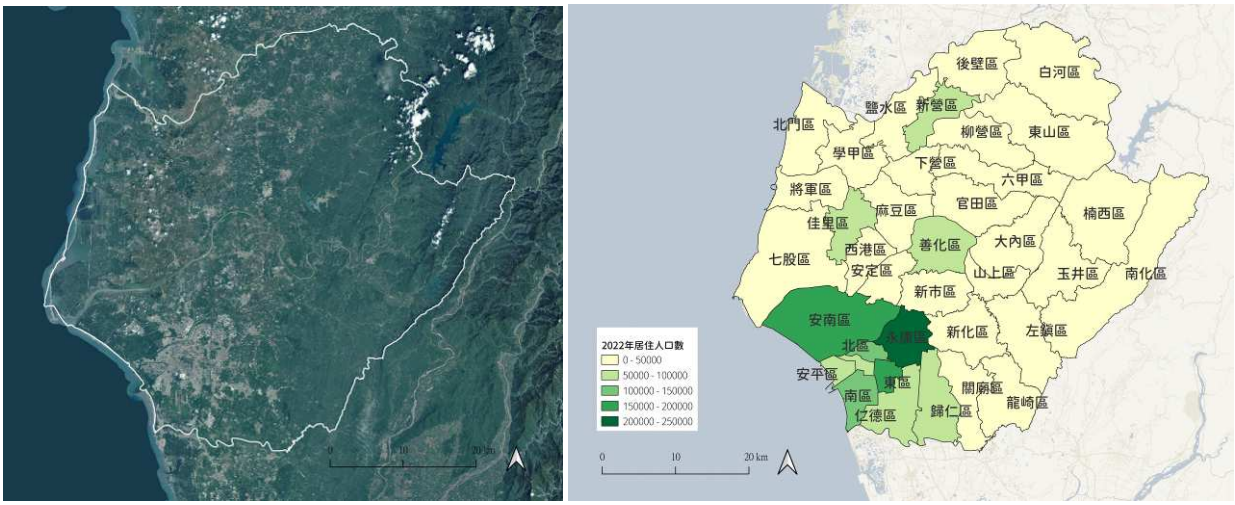


Fig. 8 (left): Aerial photo of Tainan City. Fig. 9 (right): Tainan City population distribution map in 2022

4 ELECTRICITY CONSUMPTION

4.1 Distribution of electricity consumption in residential and commercial sectors

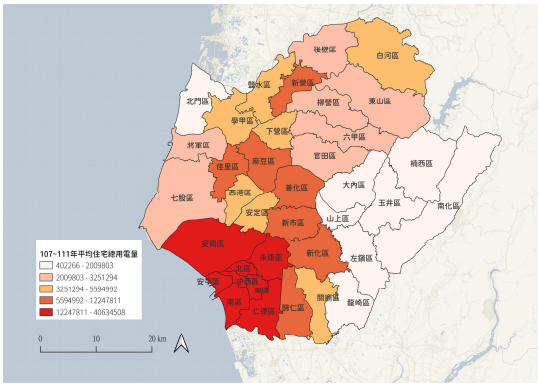
Based on the statistical data from the Taiwan Power Company for the years 2018 to 2022, an analysis of the pure residential electricity consumption in various districts of Tainan City reveals a strong correlation between residential electricity usage and the degree of urbanization. The areas which are highlighted in red (Fig. 10), particularly concentrated in the southwest, represent the city center of Tainan and exhibit the highest levels of electricity consumption, which gradually diminishes outward. In contrast, the white areas on the eastern side, closer to the mountainous regions, demonstrate lower electricity consumption and reflect the lower population density in these rural areas. This underscores the fact that urban areas exhibit higher electricity demand due to their larger populations.

Due to the high degree of mixed land use in Taiwan, there is no clear boundary between residential and commercial buildings in the city. Therefore, to be more consistent with the domestic electricity consumption in the city, this study investigated the electricity consumption of low-voltage electricity in residential and small businesses. According to research results, particularly prevalent in urban areas with more intensive commercial activities, the analysis still confirms that urban regions exhibit relatively higher electricity demand compared to rural areas (Fig. 11). In contrast, rural areas tend to have lower intensity in commercial development, suggesting a lower electricity consumption. This highlights both the higher electricity demand in urban areas compared to rural ones and the potential for greater energy conservation and efficiency measures in urban settings.

4.2 Average monthly electricity consumption of each residential household and classification

After dividing the total electricity consumption of pure residential areas by the number of households, the average monthly electricity consumption per household can be calculated. Visualizing this data reveals a correlation with the degree of urbanization, where more urbanized areas tend to have higher average monthly electricity consumption per household (Fig. 12). However, when calculating the average residential electricity consumption per capita, it can be found that there is no significant correlation with urbanization. However, the average residential electricity consumption per capita in areas with high urbanization is still high. On the contrary, in some suburbs, the average residential electricity consumption per capita is also

high. This means that although the total electricity consumption in these areas is small, the average electricity consumption is high because the number of people is also small (Fig. 12).



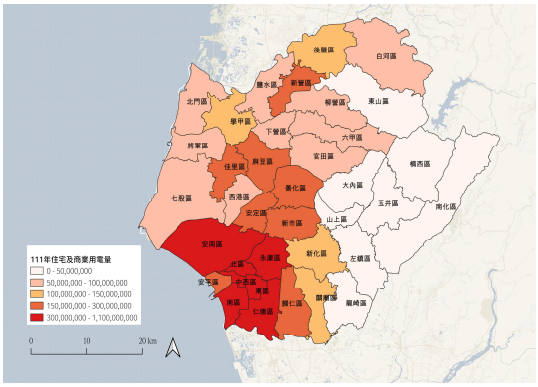
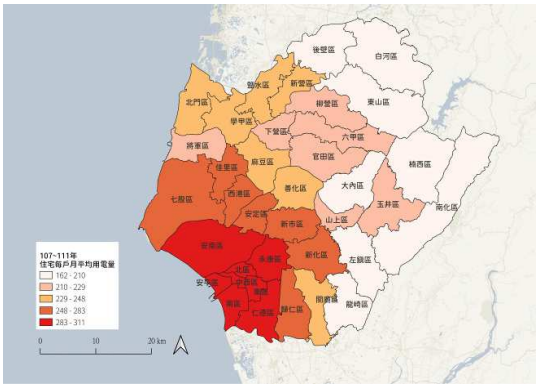


Fig. 10 (left): Average total electricity consumption of residential buildings in Tainan City from 2018 to 2022. Fig. 11 (right): Total electricity consumption of low-voltage electricity buildings in Tainan City in 2022.

Therefore, further categorization of Tainan's administrative districts based on their urbanization level and characteristics reveals five types, with each household's monthly average electricity consumption ranging from 188 kWh to 291 kWh (Fig. 14). The downtown area, characterized by the highest level of urbanization, constitutes the first category, with an average monthly electricity consumption of approximately 291 kWh per household. The second category comprises the peripheral areas surrounding the downtown, with an average monthly electricity consumption of around 260 kWh per household. The third category consists mainly of agricultural areas across the district, with an average monthly electricity consumption of about 240 kWh per household. The fourth category, dominated by agricultural zones and hilly terrain, records an average monthly electricity consumption of approximately 214 kWh per household. Finally, the fifth category represents areas with the lowest urbanization level, predominantly consisting of hilly terrain and forests, with an average monthly electricity consumption of around 188 kWh per household. (Table 1)



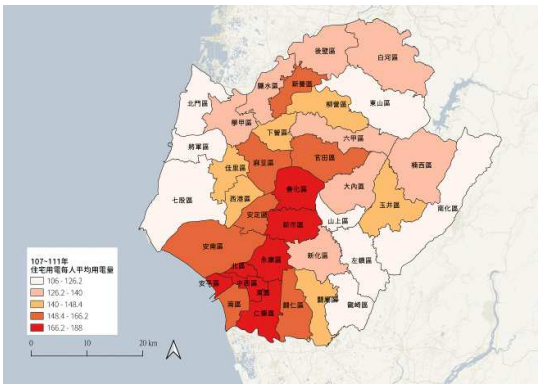


Fig. 12 (left): Average monthly residential electricity consumption per household from 2018 to 2022 in each administrative district of Tainan City. Fig. 13 (right): Average residential electricity consumption per capita from 2018 to 2022 in each administrative district of Tainan City

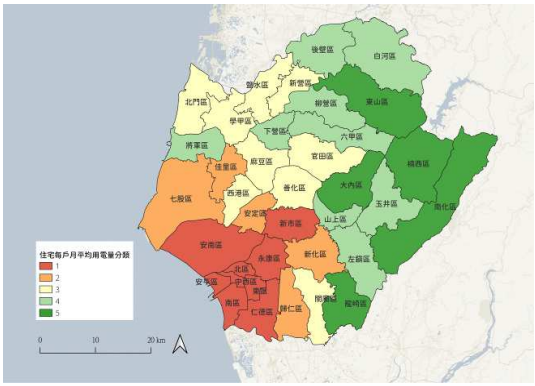


Fig. 14: Classification of administrative districts in Tainan City

Type	Illustration	Average monthly residential electricity consumption per household (kWh)
First category (1)	It has the highest degree of urbanization and is in the city center. The entire area or most of the area is a city (town) plan or urban plan.	290.63
Second category (2)	It is in peripheral areas surrounding the downtown.	259.88
Third category (3)	The whole area is mainly agricultural areas.	239.67
Fourth category (4)	The entire area is dominated by hillside conservation zones and agricultural areas.	213.97
Fifth category (5)	The degree of urbanization is the lowest, and almost the entire area belongs to forest areas or hillside conservation zones.	188.42

Table 1: Classification of average monthly residential electricity consumption per household in each administrative district of Tainan City

5 ROOFTOP PV POTENTIAL AND ELECTRICITY SELF-SUFFICIENCY

To further analyze the electricity self-sufficiency rates of different types of built-up areas, this study selects representative districts from among the 37 administrative districts of Tainan City. The first category, representing areas with the highest degree of urbanization, is represented by the West Central District. The second category, representing suburban areas outside the urban center, is represented by the Qigu District. Lastly, category 5 which is areas with low levels of urbanization, predominantly hilly terrain and forest areas, is represented by the Longqi District.

The study begins by analyzing the distribution density, number of floors, and age of buildings in these three types of areas to determine if there are significant differences. Subsequently, simulations of the potential for PV generation based on two scenarios are conducted to explore the achievement of residential and commercial electricity self-sufficiency rates in the three types of urbanized areas.

5.1 Overview of buildings' condition in each district

The West Central District, located in the old city area of Tainan City, exhibits a high degree of urbanization, resulting in dense building distribution (Fig. 15). Legally constructed building areas account for 31.54% of the total administrative district area, with buildings primarily ranging from 3 to 5 stories in height. Buildings with an age of under 30 years represent only 37.62% of the total building area.

The Qigu District, situated in the suburban area, is primarily characterized by fishpond usage due to its proximity to the Taiwan Strait. As a result, buildings are widely dispersed (Fig. 16), and settlements are concentrated in areas closer to the inland eastern side. Legally constructed building areas comprise only 0.43% of the total administrative district area, with buildings mostly consisting of 2 stories or fewer. Buildings with an age of under 30 years represent approximately 68.30% of the total building area.

District	Legally constructed building density	The ratio of buildings with an age of under 30 years	Ratio of buildings below 2 stories	The ratio of buildings between 3~5 stories	Ratio of buildings above 5 stories
West Central District	31.54%	37.62%	40%	46.1%	13.9%
Qigu District	0.43%	68.30%	78.9%	21.1%	0%
Longqi District	0.10%	42.58%	95.2%	4.8%	0%

Table 2: Buildings analysis in West Central District, Qigu District and Longqi District

The Longqi District, adjacent to the Central Mountain Range, features more sloped terrain and forested areas, resulting in even more scattered building distribution (Fig. 17). There are no distinct settlement patterns, and legally constructed building areas account for only 0.1% of the total administrative district area.

Buildings in this area mostly consist of 2 stories or fewer, with buildings under 30 years of age constituting around 42.58% of the total building area.

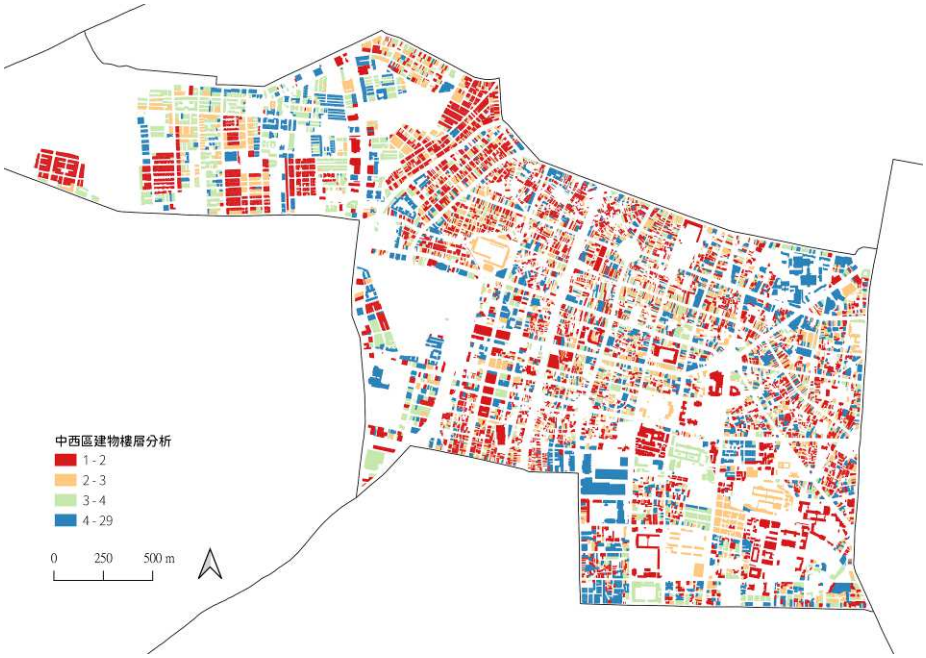


Fig. 15: Building height analysis in West Central District

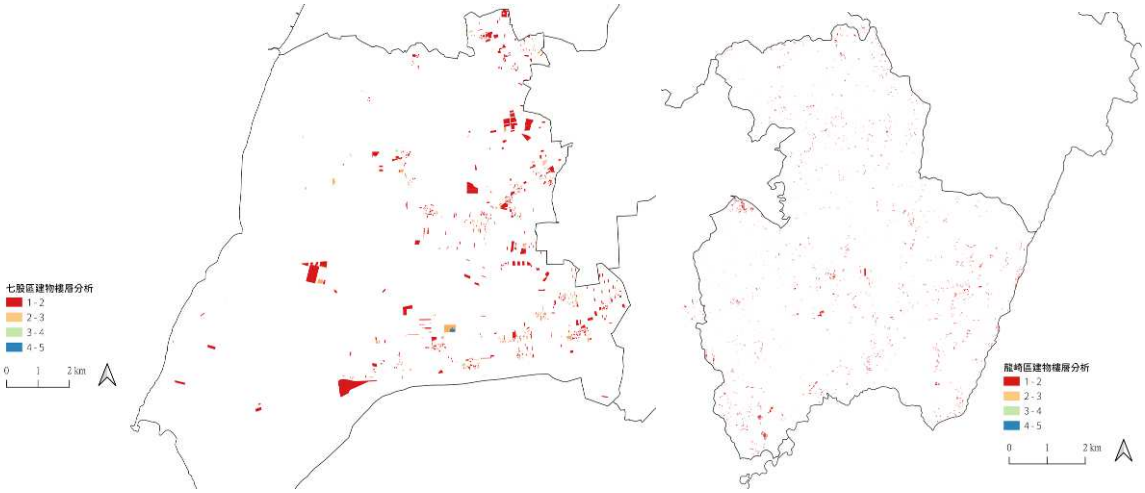


Fig. 16 (left): Building height analysis in Qigu District. Fig. 17 (right): Building height analysis in Longqi District

5.2 Rooftop PV potential and electricity self- sufficiency rate

In the calculation of rooftop PV potential, based on 50% of the projected area of legal buildings in the West Central District, Qigu District, and Longqi District, two scenarios are simulated to calculate the potential for rooftop PV development to meet actual electricity demand. This serves as a basis for formulating tailored goals and policies for solar PV development in urban and rural areas.

The rooftop PV potential is divided into two scenarios, considering that the average lifespan of buildings is 50 years while rooftop PV systems have a lifespan of 20 years. In the first scenario, the potential supply area for rooftop PV is calculated based on buildings under 30 years old, covering 50% of the total roof area. In the second scenario, it is assumed that all buildings can install solar panels in the future, with the same calculation method applied.

For the self-sufficiency rate calculation, the electricity usage from 2022 for low-voltage buildings is considered to better reflect general electricity consumption patterns. The results of the self-sufficiency rate calculation show that in the first scenario, the West Central District, which has a higher degree of urbanization and older buildings, has the lowest self-sufficiency rate at only 13%. In contrast, the Qigu District achieves the highest rate at approximately 26%, while the Longqi District reaches 23%. In the

second scenario, with increased potential for rooftop PV, the self-sufficiency rates improve. The West Central District increases to 33%, the Qigu District to 39%, and the Longqi District sees the most significant improvement, rising to 54%.

Comparing self-sufficiency rates across different types of built-up areas reveals that while the West Central District has more buildings, its urban electricity consumption is higher, resulting in a maximum self-sufficiency rate of only 33%. Conversely, rural areas like the Longqi District, despite having fewer rooftops suitable for solar panels, achieve higher self-sufficiency rates of up to 54%, indicating greater potential for renewable energy self-sufficiency in rural areas. Therefore, efforts to promote rooftop PV installation should be strengthened in rural areas.

District	Electricity consumption of low-voltage buildings in 2022(kWh)	Rooftop PV power generation of buildings under 30 years old (kWh)	Self-sufficiency rate	Rooftop PV power generation of all buildings (kWh)	Self-sufficiency rate
West Central District	384,294,465	48,125,802	13%	127,919,393	33%
Qigu District	80,067,651	21,118,247	26%	30,921,360	39%
Longqi District	7,456,496	1,720,407	23%	4,040,161	54%

Table 3: Rooftop PV potential and self-sufficiency rate in West Central District, Qigu District, and Longqi District

6 CONCLUSION

In Taiwan, solar energy has been a development goal in recent years. However, the government has focused solely on the target of installed PV capacity, lacking long-term policy goals and a reevaluation of energy supply and demand. This has led to the current phenomenon of disorderly development in PV facilities, with large-scale ground-mounted PV installations encroaching upon agricultural land or fish ponds, raising concerns about the destruction of green and ecological resources. Therefore, the development of renewable energy and the logic of land ethics and land planning must be established to avoid aggressively promoting energy transformation while damaging important national land resources. Currently, Taiwan has set a target of 20GW of installed PV capacity by 2025, without clear spatial planning or development strategies and guidance for different types of areas. With the population growth and construction of new buildings in different regions, failure to promptly establish appropriate policies to make the most of these built-up areas could lead to a continuous increase in the amount of electricity that ground-mounted PV must generate. Therefore, the promotion of rooftop PV should be given more attention and foresight, but it should not lack a careful evaluation process.

This study attempts to explore the self-sufficiency rate of rooftop PV based on residential and commercial electricity consumption in built-up areas. From the results of this study, rural areas have a high potential to achieve self-sufficiency in electricity consumption through rooftop PV, thus future efforts should focus on promoting electricity self-sufficiency in rural areas. Although the degree of self-sufficiency in urban areas is limited, the high population and building density in cities also provide opportunities to reduce electricity demand through energy-saving measures. Additionally, renewable energy generation, including solar PV, is relatively unstable compared to traditional coal-fired or nuclear power generation and is also time-dependent. Therefore, the stability of the future power system is crucial. Currently, Taiwan's electricity distribution is mainly centralized production by Taiwan Power Company, distributed to households or industries, posing high risks and energy losses in a centralized power grid. Electricity has always been essential for human life, production, and transportation. Rooftop PV provides an opportunity for power system reform by increasing the popularity of distributed energy sources through public participation, allowing local power needs to be produced locally, and ensuring the efficient use of energy. As a result, urban areas should also re-examine urban infrastructure, actively promote the development of community-based PV installations, and complement them with energy storage and smart grid deployment to improve grid layout, reduce unidirectional power transmission, and increase electricity efficiency in urban areas.

In terms of future research recommendations, because this study only focuses on the potential of rooftop PV installations in built-up areas, it has not considered other renewable energy sources that could be developed in built-up areas, such as small wind power and small hydroelectric power. Additionally, with technological advancements, buildings can integrate solar energy not only on rooftops but also on facades through Building-Integrated Photovoltaics (BIPV). Therefore, future research on renewable energy simulations in established areas could explore more diverse scenarios. In legal terms, other possible renewable energy sources should be included, and the integration of solar energy into buildings should be encouraged, rather than just focusing on rooftop PV. In conclusion, specific regions should not bear greater sacrifices, and appropriate regulatory measures should be used to maximize the use of available buildings and spaces in built-up areas, allowing areas needing electricity to generate their own power, and reduce unnecessary damage to environmental resources. If electricity self-sufficiency cannot be achieved within built-up areas, the government should use growth management measures to maintain fair development between regions, achieving a more just development of renewable energy.

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Balancing Heritage Preservation and Regeneration in Riyadh: Objectives and Considerations

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1 ABSTRACT

Heritage regeneration and redevelopment of city centers are essential strategies for long-term sustainability and resilience. These processes aim to develop heritage assets by transforming them into sustainable cultural spaces to meet the city's environmental, social, and economic needs. These processes create vibrant, inclusive, and sustainable urban spaces while maintaining and enhancing the unique character and identity of the city by triggering city dynamics in response to its rich heritage as an economic development engine and as a tool to attract new investments and businesses. This paper explores the interaction between heritage preservation and regeneration, a complex and multifaceted phenomenon that requires thoughtful approaches. This interplay poses a variety of challenges and opportunities for cities' social, economic, and cultural dynamics. Using heritage regeneration to redevelop cities, this paper examines the ideas that make heritage centers a powerful force in developing methods including cultural heritage in urban planning. This paper limits its scope to Riyadh, a city with a rich cultural heritage and a rapidly evolving urban landscape. It explains how applying the strategies of heritage regeneration has intensified in many historically significant neighborhoods and central areas in Riyadh city and provides an insightful demonstration of how heritage preservation and regeneration are interconnected by offering a holistic representation of what has changed in Riyadh Heritage Center. This includes understanding heritage considerations and setting clear objectives for city center development. A balance between heritage regeneration and preservation is also stressed in the paper. The paper concludes with some results that indicate that establishing a cohesive urban identity requires a balance between traditional and modern images. In addition, it requires promoting cultural resources, such as cultural heritage.

Keywords: balancing, preservation, revitalisation, regeneration, heritage

2 INTRODUCTION

Heritage preservation is a critical tool to enhance the public's appreciation and understanding of valuable cultural resources that form part of their identity. In line with developmentalism, heritage regeneration has also picked up momentum globally through various attempts by governments throughout history to achieve overall development (Said et al., 2013). They also added that it is a strategy that implements the discourse of 'cultural improvement' and beautification, supported by many existing investments.

Redevelopment projects involve the development of an area that has already been occupied by structures, providing a way to reverse the area's physical, social, and economic decline. To stimulate economic growth and community development, it is imperative to emphasize the repurposing and revitalization of underutilized and vacant properties.

This study discusses the importance of balancing preservation with heritage regeneration, which is particularly difficult to maintain (Kong and Yeoh, 1994). Thus, the development concepts of heritage centers are based on modern, well-developed plans for revitalizing and reusing them.

As for the scope of this research, regeneration means revitalizing a region with social, physical, and economic activities. Previous work described it as a 'growth industry' since heritage assets can play a central role in successful regeneration – they represent an opportunity rather than a constraint (BPF, 2013). Heritage regeneration has significant economic benefits that extend beyond the individual building to the surrounding area and community. Heritage regeneration is a global phenomenon, often linked to both strategies seeking to develop so-called cultural industries and a process of 'place-making' (Pendlebury& Porfyriou, 2017).

This study examines the heritage regeneration project in Riyadh's central area as a method of urban development. Riyadh offers an urban setting that shapes the connection between heritage preservation and regeneration within the overall discourse on redevelopment practices. This is against Riyadh's ambition to become a cosmopolis and mega-destination. Under Vision 2030.

This paper discusses the importance of heritage regeneration as an instrument of urban redevelopment. The paper starts with a review of heritage and regeneration, with a focus on the Riyadh context. The second and third sections examine the projects involved in heritage regeneration in Riyadh's central area and their associated impact.

It is worth mentioning that this study brings a theoretical and conceptual approach to the sustainable regeneration of heritage buildings.

3 LITERATURE REVIEW

Built cultural heritage symbolizes the identity and history of people. It is an integral part of a nation's living memory and history. The built cultural heritage has been passed on from one generation to another. It is a fundamental element that constitutes a society's collective memory and cultural identity (Taha, 2023). It carries an identity and can be engraved with memories and meanings extending beyond its aesthetic or historic qualities and being part of a distinctive environment. In cosmopolitan cities, heritage resources play a significant role in addressing urban developments. Heritage preservation is a comprehensive review of the works available on heritage that reveals its importance. Nowadays, there are increasingly more heritage-led initiatives, preservation societies, and projects

Preservation practices emerged as a form of appreciation for heritage. Additionally, it is a means of preserving and conserving heritage that our forefathers have bequeathed to us in architectural works or products (Earl, 2003.)

The regeneration process is a major industry that has shaped today's complex urban planning system. (Kuutma, 2013). Regeneration is a planning scheme for rebuilding, improving, and introducing old heritage settings into a new, modern, and economically viable environment (Smith, 2007). Regeneration is defined as being synonymous with revitalization. However, urban regeneration is a collective picture that integrates economic, environmental, social, cultural, symbolic, and political features (Bianchini & Parkinson, 1993). It is a practice that utilizes the potential of that decline in the use of heritage buildings to improve the physical, economic, social, and cultural surroundings (Said et al., 2013). Urban redevelopment using heritage regeneration strategy as a concept and practice of revival in the historic urban environment appeared in the early 1990s. Since then, it has been a dominant practice in restoring historical cores.

Some of the more famous examples of the application of this model represent the reconstruction of the cities of Genoa and Barcelona (El Menchawy, 2008). This strategy has spread from Porto to Cairo and Bahia to Shanghai (De Cesari and Dimova 2018).

Urban redevelopment using heritage regeneration assumes a comprehensive and integrated approach to systematically rebuilding and revitalizing the urban environment. It considers all the dimensions of space and its material and immaterial data, which form the backbone of sustainable life, the identity, and the city's image. As a comprehensive process, this strategy relates to reconstructing an individual building and involves a wider urban area (Kostešić et al., 2019).

This demands a large degree of equilibrium between appropriate actions and improvements while considering the existing socio-economic networks and conservation methods and standards. When discussing the impacts and functions of heritage on urban redevelopment, we specifically focus on numerous manifestations of value concerning heritage. In the case of heritage-led regeneration, urban redevelopment involves negotiation and resistance, mainly from local communities (Skoll & Korsten, 2014; Scott, 2010).

Moreover, heritage regeneration is one of the best practices most used in redevelopment in alignment with theories and techniques for heritage preservation. Heritage preservation and regeneration can be balanced by understanding that the two concepts are not opposing but relatively supportive of each other.

In line with previous work, researchers demonstrated that preservation ensures the protection of heritage authenticity, while regeneration emphasizes making heritage assets available and useful to current or future generations. Though preservation and regeneration are two different fields, the ways of urban development that rely on regenerating heritage have met with success internationally; however, these methods and strategies have received very little scholarly attention in the Arab world in general and the KSA in particular.

Most of the existing works on urban redevelopment systems are about open space, while studies regarding heritage conservation often confine themselves only to architectural contexts and do not address its

relationship to the wider framework of city revitalization or redevelopment. In addition, urban redevelopment is a field dominated by studies on the governance and management of cities, but rarely about how it relates to heritage conservation (Song, 2017).

Based on the short preview above, this study claims that urban redevelopment in central heritage sites is a mix of heritage preservation and regeneration using this strategy, and striking a balance between both approaches in urban development projects may result in vibrant and sustainable culturally rich spaces that preserve heritage while meeting the needs of present and future generations.

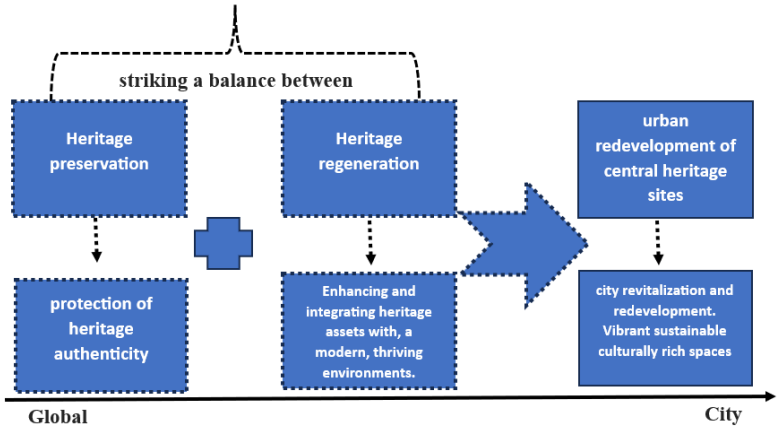


Fig. 1: The synergy between Preservation and Regeneration (Author)

4 RESEARCH METHODS

By reviewing the current literature, research, and experiences on urban heritage, including existing approaches, frameworks, case studies, and qualitative methods employed in this research, we provide a theoretical and conceptual approach to sustainable regeneration of heritage buildings and a comprehensive analysis of the correlation between heritage conservation and regeneration processes and their impact on urban redevelopment. The author uses a mixed-method approach involving built environment analysis, online searches of official websites for heritage and city development authorities in Riyadh, and thorough interviews with stakeholders.

To analyze urban redevelopment and heritage regeneration as a process, the research used multiple field trips to the selected sites and a collection of secondary sources, such as city maps, recent heritage and urban policy documents, and photos of the built environment to capture evidence of the presence of regeneration, beautification of urban spaces, and functional upgrades. The combination of these methods and the visual forms contributes to the aesthetic and value analysis of heritage sites and their relationship with urban redevelopment.

5 THE STUDY AREA: RATIONALE AND BACKGROUNDS

This research investigates urban redevelopment in Riyadh's heritage center through heritage regeneration and preservation. Very few studies of this central district have considered urban redevelopment related to heritage preservation. This research is important because it will develop an analytical framework for urban redevelopment and analyze the outcome of combining and balancing heritage preservation and regeneration as strategies to achieve urban redevelopment. The research will concentrate on the historical heart of Riyadh, especially its central district with a political capital, a major mosque, and a busy commercial zone catering to an entire province.

The Central Area is about 1,500 hectares, which was the core of Riyadh's past, and its current character does not reflect its importance to the city as it has undergone a lot of changes over time. Consequently, it has changed its physical condition as neglect and decay are observable in many parts (ATKINS, 2012).

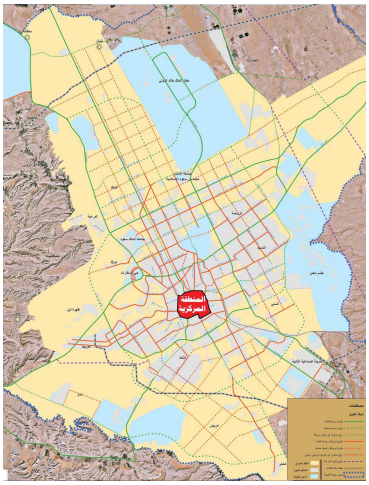
5.1 The cultural significance of the center of Riyadh

The Old Riyadh is characterized by its unique architectural character that reflects architecture through several symbols (Taha, 2023). The Center of Riyadh represents its political and administrative center. It includes the Palace of Governance, various government headquarters, and several national cultural and

heritage institutions. By the same token, the history of Riyadh's old center dates back to the 1800s, when it stood as the center of the ancient Najd culture and still, to this day, continues to be the historic core of the modern city of Riyadh.

This region plays an important economic role at the city level. This center is also the historic center of Riyadh and is a cultural and historical treasure for Saudi Arabia, showcasing traditional architecture and landmarks comprising a string of distinct neighborhoods. The most prominent are Qasr al Hokum, Al-Masmak Palace, and Historic Square (Heritage Commission, 2021). Its narrow streets and markets offer insight into past daily life, reflecting Saudi folk culture. This center hosts events and activities. The area contributes to cultural enrichment and maintains inter-generational communication. Overall, conserving historic centers is crucial to preserving identity, promoting cultural awareness, and attracting tourism to Riyadh.

It is important to consider the historical role of the Central Area of Riyadh in the future. Historically, the Central Area performed multifaceted functions as a political, administrative, religious, and trading center. Despite fluctuations in the area's prosperity and a period of significant change, the Central Area today retains many of the fundamental strengths that underpinned the area's historical importance. These include government and other major public functions, including law courts and ministries, in addition to commercial, retail, and other activities (ATKINS, 2013). Throughout the last century, the region has been rich in historical and cultural assets that reflect the city's development and the Kingdom's formation. There is a risk of decline for these assets. A significant amount of effort will be required to preserve, protect, and enhance these assets as part of the renewal framework.



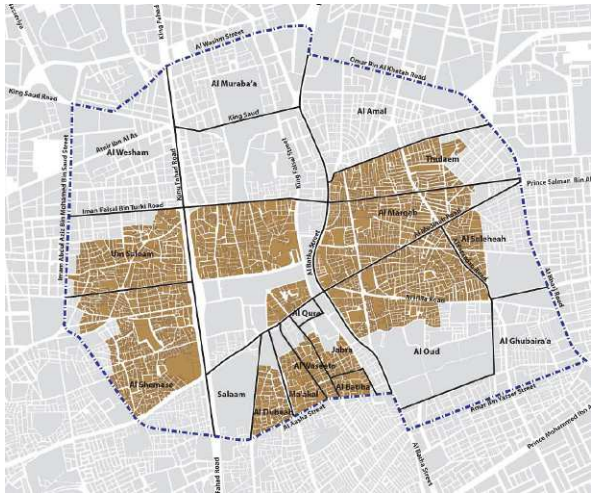


Fig. 2 (left): The Central Area with the Overall City Urban Growth. Source: (AL-Riyadh Development Authority: ADA). Fig. 3 (right): Heritage Structures within the Central Area (ATKINS, 2013).

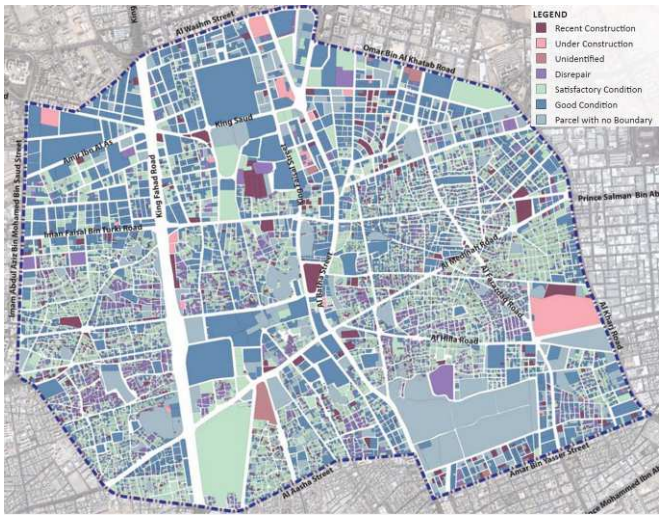


Fig.3: The physical condition of the buildings in Riyadh Center (ATKINS, 2013).

5.2 The physical condition of the center of Riyadh

The physical condition of the central area before the development project began was bad, and Saudi residents were forced to relocate. Their properties have become difficult and expensive to maintain because of their departure. In addition to the congestion, inadequate parking, poor public transportation provision, and equally poor infrastructure, large areas of the south-western sector, south and mid-central sector, and mid-eastern sector suffer from poorly built conditions and include Organic Mixed Use (High-Density Residential Dominant) Areas. Conversely, Northern areas are generally in better condition. The Central Area is a mixed-use (heritage dominant) area with many heritage structures and a mix of uses with vibrant shopping streets. This central area requires more intervention than areas limited to the public realm and facility upgrades.

Fig.4: The physical conditions of the buildings in the center of Riyadh. Source: author.

Over the past decades, rapid urban development in Riyadh has caused residents to move from downtown to other parts of the city, resulting in a decline in urban use. This attitude encouraged expatriates to settle in Riyadh downtown and replace residential uses with uses that support commercial activities like warehouses due to low rents that accompanied the deterioration of the area's urban situation. As a result, the downtown's role and main functions were negatively affected. The remaining heritage building assets must be protected since many have already been lost.

This regeneration project in Riyadh will enhance the quality of life in this central area. Additionally, this will make it a desirable residential area for native city residents (Saudis). By implementing such projects, foreign arrivals in the historic center will be reduced because of rising real estate prices after its development, which will allow the center's original demographic of Saudis, particularly those who own businesses within the historic center, to be restored. In the longer term, the focus would be to retain the share of legal non-Saudis employed locally. Saudi nationals' share will increase by providing employment opportunities and new housing areas served by community facilities and services.

Over the 20th and 21st centuries, Riyadh has experienced rapid growth. There are buildings from each of these decades in the city's center. As Riyadh experienced rapid urban expansion, the central area became neglected and disorganized. The city center's use and users changed as people moved to newly constructed suburban areas: more expatriates settled there. Due to affordable rents, low-income workers reoccupied many abandoned (and decaying) properties and used some as warehouses to store their supplies. Most historic center residents are foreigners who work in one of the souks or small businesses nearby (Klingman, 2021).

Riyadh Downtown is characterized by several historical landmarks, which resemble a central icon for most Saudis. It has many plazas and traditional markets, some mud residential buildings have been distorted, and many are in pristine physical condition (ATKINS,2013). The center has no contemporary projects or modern buildings. Moreover, most modern developments in Riyadh have occurred in the north, outside the buffer zone of the central area

6 HERITAGE REGENERATION AND PRESERVATION: A PATH TO RIYADH CENTER REDEVELOPMENT:

The following section provides an overview of the key developments and projects—existing, planned, or under implementation—that help set the general development context for the Central Area regeneration project, which included cultural heritage as a vital component of beautifying and shaping urban space creation. (AL-Riyadh Development Authority, 2015: ADA).

Because of the importance of this center, local authorities are planning to revive the area and make it fully part of the city. To this end, a regeneration plan has been implemented to build an attractive, lively, and eco-friendly city core. (ATKINS, 2013), (AL-Riyadh Development Authority, 2015: ADA)

The paper here will examine and discuss the close links between heritage regeneration and heritage preservation as a tool for urban redevelopment in more detail in the case of Riyadh by analyzing how these strategies will turn its center into a commercial mixed-use destination using specific heritage destinations and iconic architecture. It is one of the key goals that formulated the strategic framework of Saudi Vision 2030, which focuses on making this center and the whole of the city among the top 100 cities in the world due to its valuable cultural heritage. A renewed city center, internationally recognized and enjoyed by all as the living heart of Riyadh.

6.1 Developing Riyadh's Central Area: Preserving and Regenerating Heritage in Three Key Areas.

Three major areas of the Central Area have been identified. For preservation, rehabilitation, and regeneration, each of the three areas identified will undergo a comprehensive redevelopment based on a master plan for the area. These three areas are shown above in the figure below and are briefly described below:

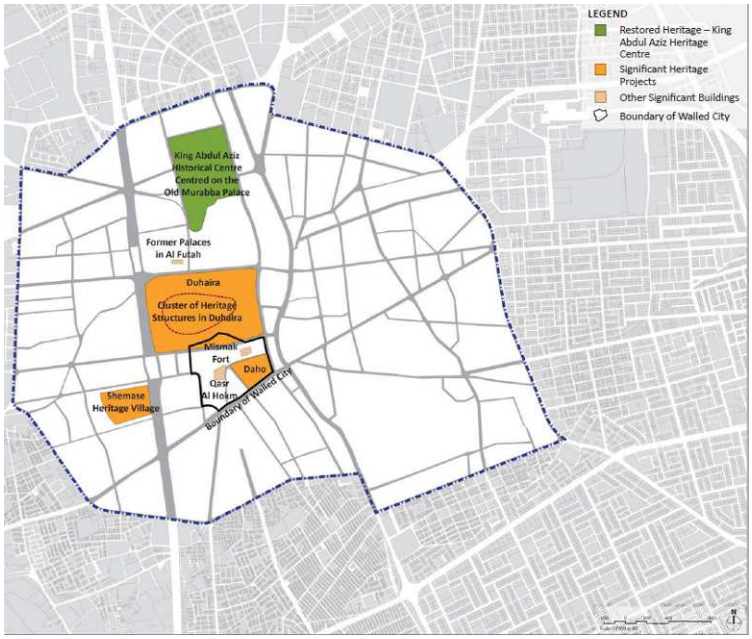


Fig.5: Heritage Led Regeneration Projects Source: (Atkins,2013)

Al Dhahira district project:

This is regarded as one of the most significant projects under consideration now and is designed to revive the Al Dhahira, which is within the central heart of Riyadh. Large sections of this area will be regenerated while keeping heritage buildings in many of the city's remaining original urban contexts. This project received preliminary approval from the AL-Riyadh Development Authority. The purpose of the "Dhahira district" development project is to reinforce the urban structure between the Palace of Government area and the King Abdulaziz Historical Center and to make the Dhahira area a large commercial center of high standard. It consists of commercial, office, and residential facilities, in addition to providing various service facilities.

The implementation of the Dhahira area development project is taking place. Through several governmental and private agencies, namely the Supreme Commission for Riyadh Development, Riyadh Municipality, and the Saudi Commission for Tourism and National Heritage, the plan aims at preserving it, bringing back activities proper to it' and rehabilitating, restoring, and preparing buildings of heritage for reuse that preserve their urban identity elements and components in it and attracting visitors.

The northwestern side of the place is the updated design of the area. The most significant landmark of this project is the hotel buildings, which are distinguished by their superstructures. Public transportation will be linked to the area by establishing a public transportation station.

Al Dhahira district project: This is considered one of the largest projects currently under consideration and aims to regenerate the Al Dhahira district located within the central spine. This area will be comprehensively redeveloped while maintaining and restoring many of the city's remaining heritage buildings within their original urban context.

The uses were varied in the new design of Al Dhahira. As an illustration, the distinctive texture of the mud buildings was taken advantage of and used as residential units, with the addition of modern residential buildings of multiple heights in the western part of the area, followed by a group of office buildings adjacent to King Fahd Road. Most of the commercial uses were concentrated on the main internal streets of the area, while the cultural and touristic uses were distributed in the central part of the area. This area is considered the strip linking the Palace of Governance area and the King Abdul Aziz Historical Center.

Fig.6: View of Al-Dhahira neighborhood and Alshmisi after development (ATKIN-2013)

Al Daho redevelopment project: Al Daho is one of the oldest parts of Ad Deirah and occupies a strategic location within the 200-year-old city walls of Riyadh. Its mud-brick structures lay in ruins for many years before being designated for conservation and rehabilitation by the Royal Commission for Riyadh City, RCRC (Ayes Saint Gross, 2015). In addition, the site should be developed into a mixed-use tourist attraction for national and international visitors. This second heritage-led regeneration project will reinvigorate a core commercial district of the Central Area, creating a significant landmark tourist attraction that builds on the success of the Qasr Al Hokum development (RCRC, 1989). The AL-Riyadh Development Authority leads this project, ADA, and is in the early stages of construction, with demolition works already underway at the site. The importance of this project comes from the location of the Al-Daho district. The houses of this district will contain galleries of indigenous arts and crafts and indoor marketplaces.

Fig.7: View of Al-Daho neighborhood the current situation and after development (Royal Commission for Riyadh City, RCRC)

Al Shimisi project: Al Shimisi district is a small zone of dilapidated modern and mud brick houses west of the Central Area and is amongst the first western expansion areas outside the original walled city. The municipality plans to restore this area of Al Shimisi as a traditional heritage neighborhood to be included in the Heritage Trail. However, the Historical Village project in Al Shimisi currently remains in the initial feasibility study and data collection stages (ATKIN, 2013).

The main concentration will be conservation, rehabilitation, and restoration in each of the three development projects. In addition, each undertaking will serve as another impetus for the re-development of adjacent areas that will push forward the comprehensive rejuvenation of the Central District.

Al-Daho project and Al-Shimisi's planned heritage district constitute two existing models of heritage neighborhood revitalization. Both include mud-brick structures that have been in ruins for many years and have residential buildings. However, Al Doho is in the walled center of Riyad. It was developed to accommodate commercial functions, including governmental offices and ground-floor retail. AL Shmisi can be considered the first expansion of the center to the west direction, and it will be developed to accommodate as a heritage village, Both projects al Shimisi and Aldoho are on the edge of the heritage trail project which is proposed in the development plans. These two breakthrough models of heritage regeneration methods aim at urban redevelopment, some other good examples can be mentioned including the renovation of some mud-brick palaces in the Al Futah district.

6.2 The Proposed Central Area Heritage Trail Project

Riyadh Center's redevelopment plans also included a new tourist, cultural, and heritage route established from King Abdulaziz Historical Centre in the north to the Heritage Village, which will be constructed at Al-Shimisi District in the south. The route will cross all heritage, cultural, and entertainment landmarks at Al-Zuhairah, Al-Daho, Qasr Al-Hokum District, and Salam Park. (Royal Commission for Riyadh City, RCRC)

The development of a 'Central Area Heritage Trail' forms a key component of heritage preservation in Riyadh Center, which merges redevelopment, heritage preservation, and regeneration. This trail will be the heritage trail through the heart of Riyadh for residents and visitors, and it will describe the evolution of Riyadh from a traditional society to a modern state. The Heritage Trail will provide opportunities for active exploration, wandering, discovery, and experiencing historic places and traditional culture. (ATKIN,2013)

The Heritage Trail would lead visitors on a themed journey. Residents and visitors will catch many glimpses of Riyadh's evolution and buildings from all decades of the 20th and 21st centuries. Each one of these buildings will provide different but complementary heritage experiences. The proposed route of the Heritage Trail is identified in the figure below.

The Heritage Trail is hoped to become an important tourist attraction within the revitalized Central Area. When implemented, the route is anticipated to be carefully designed to be instantly recognizable. It will link the various cultural facilities located within the Central Sector—both historic buildings and new facilities—that will be introduced as part of the regeneration works.

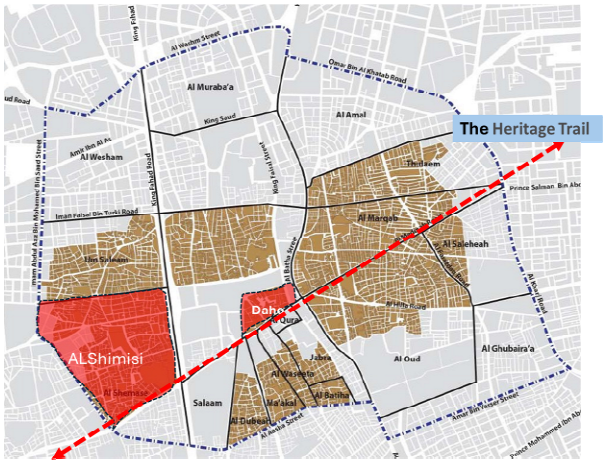


Fig.8: Central Area Heritage Trail (ATKIN,2013) edited by the author.

7 THE ONGOING KEY DEVELOPMENT PROJECTS BY AL-RIYADH DEVELOPMENT AUTHORITY (ADA)

Aligned with the vision of central area development, the AL-Riyadh Development Authority (ADA) has already taken the lead in restoring several key heritage structures within the central area by identifying important structures and their forms to ensure their longer-term protection and their restoration of dilapidated traditional and mud brick buildings to preserve them for posterity.

Several significant projects have already been identified to upgrade and enhance the Central Area while preserving key historical assets, urban form, and the area's distinct urban fabric to reconstruct several heritage neighborhoods to revive the memory of traditional everyday Saudi society.

7.1 King Abdulaziz Historical Center Project

Many projects have already been implemented, such as the King Abdul Aziz Heritage Centre (KAAHC), which reflects Riyadh's heritage, culture, and history and blends with its architectural environs. The project is part of the Qasr Al-Hukm development program carried out by the Royal Commission for Riyadh City.

The center has modern and multipurpose facilities that transform it into a cultural oasis where visitors can find entertainment and benefit from its premises. The center hosts the Public Park, National Museum, Antiquities and Museums Headquarters, Al-Murabba' Palace, Traditional Mud Buildings, Darat Al-Malik Abdulaziz, King Abdulaziz Public Library, King Abdulaziz Mosque, King Abdulaziz Auditorium, and a modern road network, in addition to many public utilities like the mosque and walkways. (Royal Commission for Riyadh City, RCRC)

The design is exceptionally environment-friendly, with vast green spaces where various trees and shrubs were planted to alleviate pollution and high temperatures, filter the air, and serve the neighboring districts.

These are all significant regeneration projects that have been implemented successfully in the recent past and will continue to play a key role in future scenarios. Some of these projects could benefit from minor enhancements, such as improvements to the public realm around Qasr Al Hokum.

Fig.9: (KAAHC) Traditional and Mud Buildings (Royal Commission for Riyadh City, RCRC)

7.2 Qasr Al-Hukm District Development Project

The Royal Commission for Riyadh City also approved in 2015 an enormous integrated plan. According to the Royal Commission for Riyadh City(RCRC), this scheme's main point is "protection and conservation of cultural heritage; preserving current commercial activities." The plans reflect remarkable development in most aspects of Riyadh's historical heart, such as improving public transport services, walkability, parks, and public spaces.

Qasr Al-Hukum District, the city's heart, is one of the most important examples that reflect the balancing between heritage regeneration and preservation and the development aims. The RCRC implemented this project, and a comprehensive strategy was developed to cover all aspects of the Qasr Al-Hukum Development Project, depending on the conclusions of the relevant detailed studies. The strategy's key axes aimed to keep expropriation within the minimum limits to open the door before private sector investments, respond to market mechanisms and order/demand requirements, and support the general tendency towards regeneration and architectural improvement rather than reconstruction.

Fig.10: Al-Adl Plaza preserved its original location, and Qasr Al-Hukum after restoration to maintain its features. (RCRC)

7.3 Celebration of Open Spaces and Integrating Intangible Heritage in Regeneration Projects

The plans of the Riyadh Downtown Development Program initiative added more space to the local open areas and parks by providing public squares and open plains connected to the public transport stations via

safe pedestrian walkways. The area stretching from the south of the King Abdulaziz Historical Centre to the Qasr Al-Hukm District will add more open spaces using the cultural and heritage route, which will be a key part of the implementation plan (Royal Commission for Riyadh City, RCRC)The expansion of the KAAHC site to the south and east is the planned 'next phase' of this renowned undertaking. The territorial expansion of the site will involve redeveloping several existing poor-quality housing and commercial areas, allowing both existing facilities and attractions within KAAHC to expand. The historical buildings that have been revamped and reformulated are within the extended center, which will have new visitor attractions. (ATKIN, 2013).

Fig.11: Ariel view of King Abdulaziz Historical Center (Royal Commission for Riyadh City, RCRC)

The plan also included expanding Salam Park eastward, establishing public gardens and parks to serve the area and the city in general, and afforestation along the main roads and streets. This development contains large areas of passive and active recreational open space that are a key attraction for residents of the Central Area and the many visitors to the area. To help address the considerable latent demand for large open spaces and retreat areas in the city. (ATKIN, 2013).

Fig.12: View of AlSalam Park after extension (Royal Commission for Riyadh City, RCRC)

The King Abdul Aziz Historical Centre (KAAHC) and Salaam Park projects developed by the AL-Riyadh Development Authority (ADA) have established two of Riyadh's most significant landscapes, open spaces, recreational areas, and celebration spaces. Those projects represent a very important example of balancing heritage regeneration and preservation while considering urban redevelopment methods, in addition to the efforts that have been made to include intangible heritage during regeneration projects to create synergy between heritage and modernity. These initiatives are vital for bringing life and meaning to the physical transformations in the area. By incorporating intangible heritage, such as traditional practices, cultural expressions, and social rituals, into regeneration projects, a deeper connection to the historical and cultural significance of the area can be established. This approach not only preserves the tangible aspects of heritage but also ensures that the intangible elements that define the identity and character of the historical center are safeguarded and celebrated. Integrating intangible heritage adds richness and authenticity to the regeneration projects, creating a harmonious blend of tradition and modernity that enhances the overall experience for visitors and inhabitants.

8 DISCUSSION

This paper analyzes the development plan for downtown Riyadh, Saudi Arabia's capital. Rapid development and modernization have changed the central area and the rest of the city. However, a significant number of major heritage and cultural assets remain that have the potential to provide future generations with an insight into how life once was in the city.

Based on the strategies discussed in this paper, the physical environment in most of these centers can be developed through regeneration. The analysis indicates that the proposed regeneration framework implemented in Riyadh effectively dealt with the Central Area's heritage regeneration and preservation

needs. Urban projects seeking to promote Riyadh, which falls in the city's center, contributed to conservation and urban planning.

The Central Area will showcase Saudi Arabia's unique heritage. It will promote the Kingdom as a cultured, civilized, vibrant, beautiful, peaceful, and global city. Protection and enhancement of these key assets must remain a fundamental component of Central Area renewal.

The development project in Riyadh's central area represents a notable success in unveiling past traits in a modern way. The Royal Commission for Riyadh City was keen on highlighting the originality of the area, which represents the city's cultural heart, by transforming Riyadh's historic center into a national cultural center. This is given the city's pioneering role as Saudi Arabia's capital. Additionally, developing the historic districts of a city serves as the nucleus of urban and cultural development, ensuring sustainable development. (Royal Commission for Riyadh City, RCRC), in a grand move to transform the central downtown into a polished urban destination, which emphasizes the importance of synergy and integration between preservation and renewal approaches to achieve comprehensive urban renewal and development for city centers.

It is imperative to note that some urban redevelopment schemes used in Riyadh required the demolition of some neighborhood buildings and their replacement with a new urban structure. This approach highlights the importance of blending rehabilitation, adaptive reuse, and rebuilding deteriorated or dysfunctional structures. It also considers the significance and integration of the current heritage fabric. These urban redevelopment schemes are used in the southern zone of Al Shimise because of the existing poor quality residential areas and buildings, which permit the replacement of many of the neighborhood's buildings with a completely fresh urban structure as a tool to improve the southern Areas via proposing new residential development, which will replace the poor quality 'Arabic house' style. This development will take advantage of the existing street patterns and urban form reflective of this older city area (See Fig 6 above). This development will be done along with renovation and renewal of the public realm and community facilities and services.

It is important to note that, despite the significant improvement of souks and bazaars which have developed within the Central Area, particularly in the inner commercial core, and the enhancement of connectivity between the inhabitants and the heritage center, a low level of community participation appears to be evident in the planning process for development for several reasons. These reasons are the absence of participation, the unwillingness of individuals to participate, and the inability of urban authorities' media platforms to interact with local communities effectively (Aldegheishem, 2023).

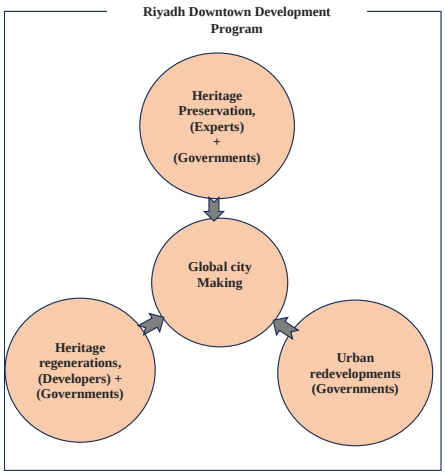


Fig.13: The relation between Heritage regeneration, Preservation, and Urban redevelopment. Source: author.

9 CONCLUSION

This article provides a better understanding of heritage's role in urban redevelopment and renovation.

Heritage preservation is a dynamic and evolving process fueled by tangible and intangible elements. Based on the local socio-cultural context, these practices draw on various methodologies. Even though preservation and development are two distinct issues, heritage regeneration can be used in the fight against urban decay. Furthermore, it can serve as a means of repurposing space and revitalizing historic areas. This increases the

population's opportunities and contributes to economic development in the cities' central areas of cultural importance. This is if heritage regeneration practices involve improving the environment and maintaining a desirable place to live. Moreover, it should mention the social aspects of development along with the economic and physical ones. Successful regeneration methods can also lead to the loss of unique townscape characteristics, so heritage preservation should be integrated into urban development.

This study illustrates how local governments and developers actively use heritage as a soft but powerful governance tool in urban redevelopment programs. By combining heritage renewal and preservation, integrated planning can be achieved, which integrates both tangible and intangible aspects of heritage.

Redevelopment strategies led by heritage regeneration have a significant impact on local communities. They are intended to enable meaningful and positive change in various city contexts. In addition, they are intended to enable heritage to fulfill its symbolic functions. Therefore, any heritage regeneration strategy should be comprehensive, interdisciplinary, and participatory. In addition to integrating heritage preservation with modern redevelopment, all urban actors and institutions must be involved in the urban planning process and regeneration projects in a way that resonates with local communities to ensure that their insights, perspectives, and aspirations are included in decision-making.

Considering the differences between each component of Riyadh's heritage center, the urban redevelopment of its center represents a dynamic and complicated process involving multiple levels of institutions and requiring long-term negotiations. Accordingly, the paper recommends focusing on policy and public involvement in historic area preservation and regeneration.

The need to involve the public in decision-making on the future of their cities is important, as the locals are the end-users of every regeneration scheme and, therefore, are responsible for ensuring the sustainability of their area, making them appreciate the place more.

Based on the methodology applied to the Riyadh Center, it is proven that heritage regeneration can be an effective tool for urban redevelopment in central areas as a contemporary placemaking program if a systematic approach is used to manage the interaction between the three main branches: heritage preservation, heritage regeneration, and urban redevelopment. Accordingly, in the context of Ryiadh, the paper suggests that enforcement measures, sustainable planning measures, and heritage partnerships are needed to solve problems in heritage centers.

This study is a fundamental starting point for future research and practical projects. It underscores how critical it is to recognize a range of perspectives on heritage regeneration. This provides a basis for more inclusive and comprehensive approaches.

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Bedarfsverkehr im ländlichen Raum zur Sicherung der letzten Meile, Analyse erfolgreicher Fallbeispiele aus dem Bundesland Salzburg

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1 ABSTRACT

Basierend auf den bisherigen Arbeiten des Instituts für Verkehrswesen zum Thema bedarfsgesteuerter Verkehr wurde gemeinsam mit dem Land Salzburg die Frage aufgeworfen, welche Erfolgsfaktoren eine Rolle spielen, damit bedarfsgesteuerte Verkehre ihre Initialphase überstehen (oft ausgestattet mit Anschubfinanzierung von Bund und/oder Land) und sich als fixes Standbein für die erste/letzte Meile des öffentlichen Verkehrsangebots in der Region etablieren können. Als Fallbeispiele wurden der W3-Shuttle (Gemeinden Pfarrwerfen/Werfen/Werfenweng) in den Jahren 2021 und 2022, der Walsiebus (Gemeinde Wals-Siezenheim) im Jahr 2022 und das Loigom Shuttle (Gemeinde Leogang) im Jahr 2023 untersucht. Dabei wurden Nutzerinnen, Nutzer, Nichtnutzerinnen und Nichtnutzer des Angebots befragt, sowohl Einwohnerinnen, Einwohner, Einpendlerinnen, Einpendler, Touristinnen, Touristen als auch Tagesgäste. Parallel dazu wurden Stakeholderinnen- und Stakeholder-Interviews durchgeführt. Es konnten dabei Initiatorinnen, Initiatoren, Betreiberinnen, Betreiber, Betreuerinnen und Betreuer der Bedarfsverkehre interviewt werden sowie Vertreterinnen und Vertreter von Organisationen, die mit dem Angebot kooperieren. Die untersuchten Bedarfsverkehre unterscheiden sich teilweise im Angebotsdesign und bei den Nutzerinnen- und Nutzergruppen. So ist das W3-Shuttle ein fahrplanbasiertes Angebot, während der Walsiebus und das Loigom-Shuttle nur Betriebszeiten anbieten, zu denen das Shuttle bestellt werden kann. Während Leogang und die Gemeinden des W3-Shuttles sehr touristisch geprägt sind, spielt in Wals-Siezenheim der Tourismus nur eine untergeordnete Rolle. Gemeinsamkeiten sind, dass der Betrieb an allen Tagen der Woche stattfindet und ein dichtes Netz an Haltepunkten das Bedienungsgebiet erschließt. Alle Verkehre werden von einem professionellen Mobilitätsanbieter betrieben. Zeitkarten vom übergeordneten Salzburger Verkehrsverbund werden akzeptiert, es gibt aber zusätzlich Haustarife bei allen drei Anbietern. Bis auf den Walsie-Bus können Urlaubsgäste das Angebot mit ihrer Gästekarte gratis nutzen. Alle Bedarfsverkehre sind an das übergeordnete öffentliche Verkehrsnetz (Bahn oder O-Bus) angebunden. Die Zielgruppen sind sehr breit definiert – alle Altersgruppen, Einheimische bis Touristinnen und Touristen soll das Angebot ansprechen. Nur der Schülerinnen- und Schülerverkehr wird in keinen der Regionen mit dem Bedarfsverkehr abgewickelt.

Die Befragung hat aufgezeigt, dass die Angebote gut in der Region verankert sind, so kennen auch der Großteil der Nichtnutzerinnen und Nichtnutzer das Angebot und ein Großteil der Befragten finden das Angebot gut (78 % W3-Shuttle, 66 % Walsie-Bus und 80 %, Loigom-Shuttle). Das Shuttle wird primär für den Freizeitbereich genutzt - beim Loigom-Shuttle zu 32 %, 22 % beim Walsiebus und zu 48 % beim W3-Shuttle. Etwa jede zweite Fahrt wurde von Gelegenheitsnutzerinnen und Gelegeheitsnutzern unternommen, dies ist der Anteil der Nutzerinnen und Nutzer, die mit einem Einzelticket unterwegs waren. Bemerkenswert ist der Beitrag des W3-Shuttles auf die Verkehrsmittelwahl bei der Anreise der Touristinnen und Touristen. Der Anteil der Urlaubsgäste, die mit der Bahn anreisen und das Shuttle-Angebot nie nutzen beträgt 6 %. Bei den Nutzerinnen und Nutzern des W3-Shuttles ist der Bahnanteil bei der Anreise mit 52 % deutlich höher. Auch der verkehrliche Effekt vor Ort ist spürbar. So gaben 54 % der Loigom-Shuttle-Nutzerinnen und Nutzer, 42 % der W3-Shuttle-Nutzerinnen imd –Nutzer und 34 % der Walsiebus-Nutzerinnen und Nutzer an, dass sie die zuletzt durchgeführte Fahrt mit dem Bedarfsbus mit dem Auto durchgeführt hätten, wenn es das Angebot nicht gegeben hätte. Ein erfolgreicher Bedarfsverkehr sollte kostengünstig, niederschwellig, einfach buchbar und kundenorientiert sein. Die Mobilitätsbedürfnisse sollen mit einem Bedarfsverkehr auf flexible und verlässliche Art und Weise abgewickelt werden. Wichtig ist die Anerkennung von regional gültigen Tickets und die Integration in das bestehende ÖV-Netz inklusive Option einer vollständigen

Routenplanung über das Bediengebiet des Shuttles hinaus. Quantitativ sind die Anzahl der beförderten Personen sowie der Besetzungsgrad die wichtigsten Kriterien, um einen Bedarfsverkehr als erfolgreich anzusehen.

Keywords: Bedarfsgesteuerter öffentlicher Verkehr, letzte Meile, ländliche Mobilität, Land Salzburg, Verkehrsplanung

2 THEMENSTELLUNG

Basierend auf den bisherigen Arbeiten des Instituts für Verkehrswesen zum Thema bedarfsgesteuerter Verkehr wurde gemeinsam mit dem Land Salzburg die Frage aufgeworfen, welche Erfolgsfaktoren eine Rolle spielen, damit bedarfsgesteuerte Verkehre ihre Initialphase überstehen (oft ausgestattet mit Anschubfinanzierung von Bund und/oder Land) und sich als fixes Standbein für die erste/letzte Meile des öffentlichen Verkehrsangebots in der Region etablieren können (Klementschitz et al. 2022, 2023). Anhand von drei erfolgreichen Fallbeispielen, die durchaus in unterschiedlichen Rahmenbedingungen eingebettet sind, wurde dieser Frage nachgegangen und die Ergebnisse in diesem Paper zusammengefasst.

Es wurde dabei folgende Vorgangsweise gewählt: In einem ersten Schritt wurde das Angebot analysiert, darunter fallen die Organisationsform, das Betreibermodell, das Bediengebiet, der Fahrplan und die Preisgestaltung (Kapitel 3). Ein zweiter Schritt war die Befragung von Nutzerinnen, Nutzern, Nichtnutzerinnen und Nichtnutzern des Angebots (Kapitel 4). Parallel dazu wurden Stakeholder-Interviews durchgeführt (Kapitel 5). Es konnten dabei Initiatorinnen, Initiatoren, Betreiberinnen, Betreiber, Betreuerinnen und Betreuer der Bedarfsverkehre interviewt werden sowie Vertreterinnen und Vertreter von Organisationen, die mit dem Angebot kooperieren. Auf diese empirischen Befunde aufbauend werden in Kapitel 6 Schlussfolgerungen gezogen, die es ermöglichen sollen, zukünftige Projekte effizient zu planen und somit auch einen effizienten Mitteleinsatz von zumeist öffentlichen Geldern zu bewerkstelligen.

3 BESCHREIBUNG DER FALLBEISPIELE

Alle drei Fallbeispiele befinden sich in unterschiedlichen Regionen im Bundesland Salzburg, das W3-Shuttle im Pongau (Gemeinden Werfen, Werfenweng und Pfarrwerfen), der Walsie-Bus im Flachgau (Gemeinde Wals-Siezenheim) und das Loigom-Shuttle im Pinzgau (Gemeinde Leogang). Prinzipiell bestehen einige Unterschiede bei der Angebotsform und den Rahmenbedingungen zwischen den Fallbeispielen. Der Augenscheinlichste ist, dass das W3-Shuttle fahrplanbasiert verkehrt, wohingegen sich beim Walsie-Bus (Abb. 1a) und beim Loigom-Shuttle (Abb. 1b) der Fahrplan flexibel aus den Bedarfsanmeldungen ergibt. Dadurch ist beim W3-Shuttle auch die Fahrtstrecke (grob) vorgegeben, beim Walsie-Bus ist diese nur durch Zonen vorgegeben, innerhalb derer die Fahrtstrecke generiert wird und beim Loigom-Shuttle gibt es weder Fahrtstrecke noch Zoneneinteilung. Nachfrageseitig ist der größte Unterschied, dass im Bedienungsgebiet des W3-Shuttles und des Loigom-Shuttles Tourismus eine wesentliche Rolle spielt, der beim Walsie-Bus in der Bedeutung nur sehr untergeordnet ist.

Abb. 1a: Walsie-Bus, Foto: Gregor Husner, Abb. 1b: Loigom-Shuttle, Foto: Roman Klementschitz

3.1 W3-Shuttle

Die Organisationsform des W3-Shuttles ist – für ein Mikro-ÖV-System –relativ komplex, da es aufgrund des Umfangs und des Bedienungsgebiets eine enge Zusammenarbeit zwischen verschiedenen Gemeinden erfordert. Der Tourismusverband Werfenweng ist – auch historisch bedingt – der Hauptakteur im Shuttle-

System, die Finanzierung erfolgt hauptsächlich von den Gemeinden. Rückmeldungen in Form von Erfahrungen und Beschwerden der Nutzerinnen und Nutzer werden sowohl an die Fahrerinnen und Fahrer, an die Betreiberinnen und Betreiber, an den Tourismusverband und an die beteiligten Gemeinden vorgebracht und in regelmäßigen Teamsitzungen erörtert. Den Betrieb des Shuttles übernimmt ein professionelles Taxiunternehmen, das entsprechend beauftragt wird. Ein zusätzlicher Akteur in der Region ist der Regionalverband, der auch als Schnittstelle zum Salzburger Verkehrsverbund (SVV) und zu möglichen Förderquellen fungiert (Abbildung 2). Der Betreiber ist das Taxiunternehmen Hippolt. Die meisten Busse sind 8 Sitzer-Busse, aber bei Bedarf, wenn größere Gruppen eine Fahrt buchen, kann das Unternehmen auch Reisebusse verwenden um die Nachfrage zu decken. Die Disposition erfolgt über eine Zentrale, die den Fahrerinnen und Fahrern eine genaue Route schickt, in Form von Adressen und in welcher Reihenfolge sie angefahren werden sollen. Das W3-Shuttle bietet Personentransporte von einer Wunschadresse innerhalb des jeweiligen Bediengebietes zum vorgesehenen Zielpunkt (Bahnhöfe und Ortszentren) und umgekehrt. Fahrten von einer spezifischen Adresse zu einer anderen oder eine Fahrt von einem Bahnhof zu einem anderen Bahnhof sind nicht möglich. Weiters kann er nicht als Schulbus genutzt werden (ausgenommen Sonderfälle, wenn Schulen oder Schulveranstaltungen besucht werden, für die der Schulbus keinen Anschluss ermöglicht). Sitzerhöhungen für Kinder und Fahrradtransport müssen bei Fahrtbestellung reserviert werden, ist aber grundsätzlich möglich. Einzelfahrscheine (€ 2,70, Stand 2022) und Zeitkarten für das W3-Shuttle sind im Fahrzeug erhältlich. Kinder unter 6 fahren kostenlos, Jugendliche von 6 bis 15 Jahren zahlen den Jugendtarif. Skifahrerinnen und Skifahrer aus Pfarrwerfen, Werfen, Werfenweng und Tenneck nutzen das W3-Shuttle kostenlos für die Fahrt nach Werfenweng Skizentrum Zaglau (während der Betriebszeiten der Bergbahnen Werfenweng). Urlaubsgäste mit Werfenweng Card nutzen das W3-Shuttle ebenfalls kostenlos. Myregio-Zeitkarten des Salzburger Verkehrsverbundes sind gültig, zusätzlich das österreichweit gültige Klimaticket, SUPER s'COOL Card, und das Edelweißticket.

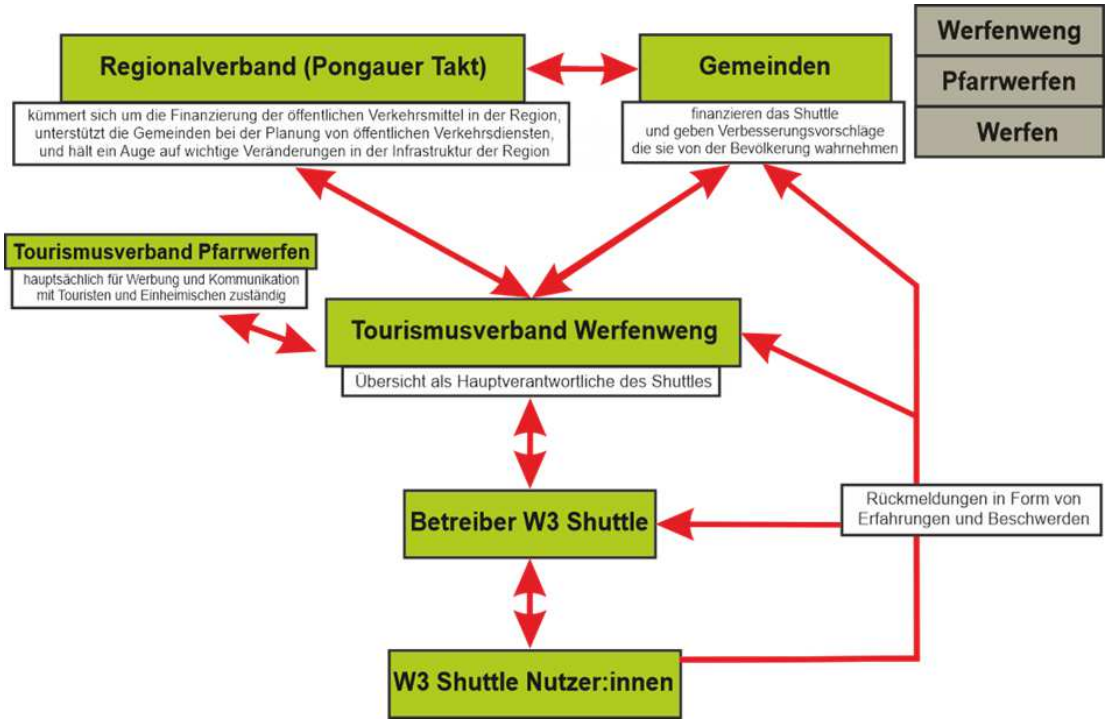

Abb. 2: Organigramm W3-Shuttle

Die Linien haben einen festgelegten Fahrplan, die Haltestellen werden nur angefahren, wenn Fahrten vorab gebucht wurden. Ohne Vorbestellung ist somit keine Mitfahrt möglich. Die Vorbestellzeit beläuft sich auf eine Stunde (alle Fahrten vor 08:00 Uhr müssen am Vortag bis 22:00 Uhr bestellt werden). Die Fahrplanzeiten sind eine ungefähre Angabe, die genaue Abholzeit wird bei der Vorbestellung der Fahrt mitgeteilt. Die Abholzeit weicht meist ein paar Minuten vom Fahrplan ab, da das Aufsammeln von unterschiedlichen Adressen in einem Ort ein paar Minuten dauern kann. Anschlüsse zur Bahn werden aber gewährleistet. Die Fahrzeiten des W3-Shuttles sind auf die Fahrzeiten der meisten Züge abgestimmt. Beginnzeiten des Betriebs sind je nach Zone zwischen 6:10 Uhr (grüne Linie) und 7:30 Uhr (gelbe Linie),

das Betriebsende liegt zwischen 18:40 Uhr (orange Linie) und 22:30 Uhr (blaue Linie). Das W3-Shuttle verkehrt täglich, das Angebot unterscheidet sich nicht zwischen Sonn- und Feiertagen und Werktagen.

3.2 Walsie-Bus

Die Organisationsstruktur des Walsie-Busses ist sehr überschaubar und hat vor allem im Vergleich zum W3-Shuttle viel weniger beteiligte Stakeholderinnen und Stakeholder (Abbildung 3). Im Prinzip besteht der Walsie-Bus aus dem Auftraggeber (Gemeinde) und dem ausführenden Unternehmen. Der Betreiber ist das Busunternehmen Krautgartner GmbH. Es werden 8 Sitzer-Elektro-Busse eingesetzt. Die Disposition erfolgt durch die Fahrerinnen und Fahrer selbst. Das Bediengebiet ist in drei Zonen unterteilt (Zonen mit unterschiedlichem Farbcode). Wenn die Fahrt gebietsübergreifend stattfindet, muss der Fahrgast je nach aktueller Auslastung den Bus wechseln (jeder Bus ist primär in „seiner“ Zone unterwegs, bei wenig Nachfrage werden aber auch umsteigfreie Verbindungen angeboten). Dieser Wechsel wird von den Fahrerinnen und Fahrern untereinander koordiniert, solche Fahrtwünsche bilden aber die Ausnahme. In diesem Fall erfolgt ein Umsteigen beim Gemeindeamt in einen anderen Walsie-Bus, die Fahrkarte kann weiterbenützt werden. Der Walsie-Bus fährt keine bestimmten Adressen an, hat aber eine Reihe von vordefinierten Haltepunkten im gesamten Gebiet, die bedient werden. Eine Fahrt ist nur von Haltestelle zu Haltestelle möglich. Die Haltestellen wurden durch eine Umfrage vor der Einführung des Walsie-Busses ermittelt und können bei Bedarf angepasst werden (z.B. ein neuer Haltepunkt oder eine Verschiebung eines bestehenden).

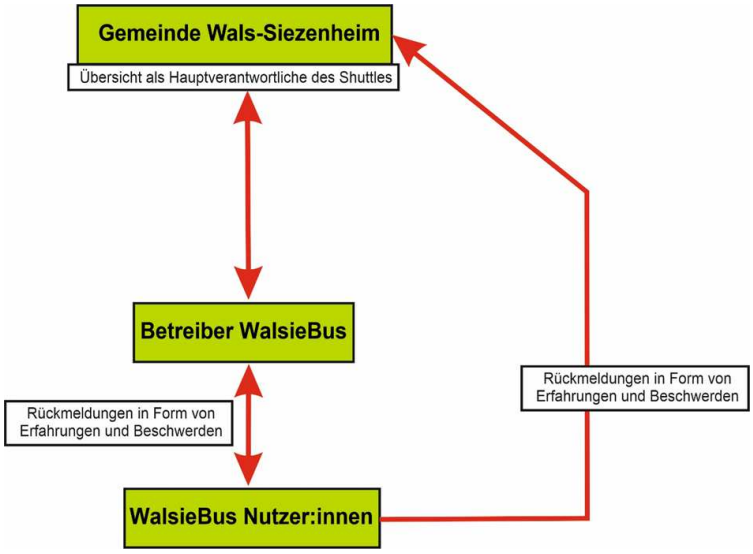

Abb. 3: Organigramm Walsie-Bus

Die Betriebszeiten sind einheitlich bei allen Zonen Montag bis Samstag von 08:00 – 21:00 Uhr und an Sonn- und Feiertagen von 08:00 – 17:00 Uhr. Fahrgäste müssen mindestens 30 Minuten vor der gewünschten Abfahrtszeit die Zeit und die Haltestelle der Abholung vereinbaren. Die Abholung erfolgt ausschließlich an den vorgegebenen Haltestellen (derzeit 82 Haltestellen im Bediengebiet). Die eingesetzten Fahrzeuge des Walsie-Busses stehen an folgenden drei Orten auf Bereitschaft, wenn gerade keine Personenbeförderung durchgeführt wird:

(1) Walserfeld – Schule (Endpunkt der Buslinie 2 – grüne Zone)

(2) Siezenheim – Ortsmitte (Endpunkt der Buslinie 28 – blaue Zone)

(3) Viehhausen – Schule (Endpunkt der Buslinie 27 – gelbe Zone)

Der Fahrpreis (Stand 2022) für eine einfache Fahrt beträgt €1,00 für Erwachsene und €0,50 für Kinder und Senioren. Als Kinder gelten Personen bis zum vollendeten 14. Lebensjahr, als Senioren gelten Personen ab dem 62. Lebensjahr. Weiters gibt es 10er und 30er Blocks zu kaufen. Die SVV-Jahreskarte des Salzburger Verkehrsverbunds wird anerkannt.

3.3 Loigom-Shuttle

Das Loigom Shuttle wird derzeit (Stand Juli 2023) im Rahmen eines Pilotprojekts größtenteils durch eine Förderung des Landes Salzburg finanziert, ergänzt durch Mittel der Gemeinde Leogang sowie des Tourismusverbandes Saalfelden-Leogang. Das Angebot ist im Salzburger Verkehrsverbund (SVV) integriert. Der Betrieb erfolgt auf der Basis einer Bestellung des Verkehrsverbundes in Abstimmung mit dem ÖPNV Pinzgau und der Gemeinde Leogang, so wie auch der konventionelle Linienverkehr in der Region. Auftragnehmer ist das Busunternehmen Postbus. Der Betrieb des Loigom Shuttles wird vom Subunternehmer Salzburger Mietwagen- und Reiseservice für den Postbus durchgeführt.

Rückmeldungen in Form von Erfahrungen und Beschwerden der Nutzerinnen und Nutzer werden zumeist direkt an die Fahrerinnen und Fahrer, den Tourismusverband und an die Gemeinde Leogang vorgebracht. Dabei ist es oft möglich auf kurzem Weg Veränderungen zu erörtern und durchzuführen. Darüber hinaus besteht mit allen beteiligten Akteuren eine rege Zusammenarbeit und ein reger Austausch (Abbildung 4).

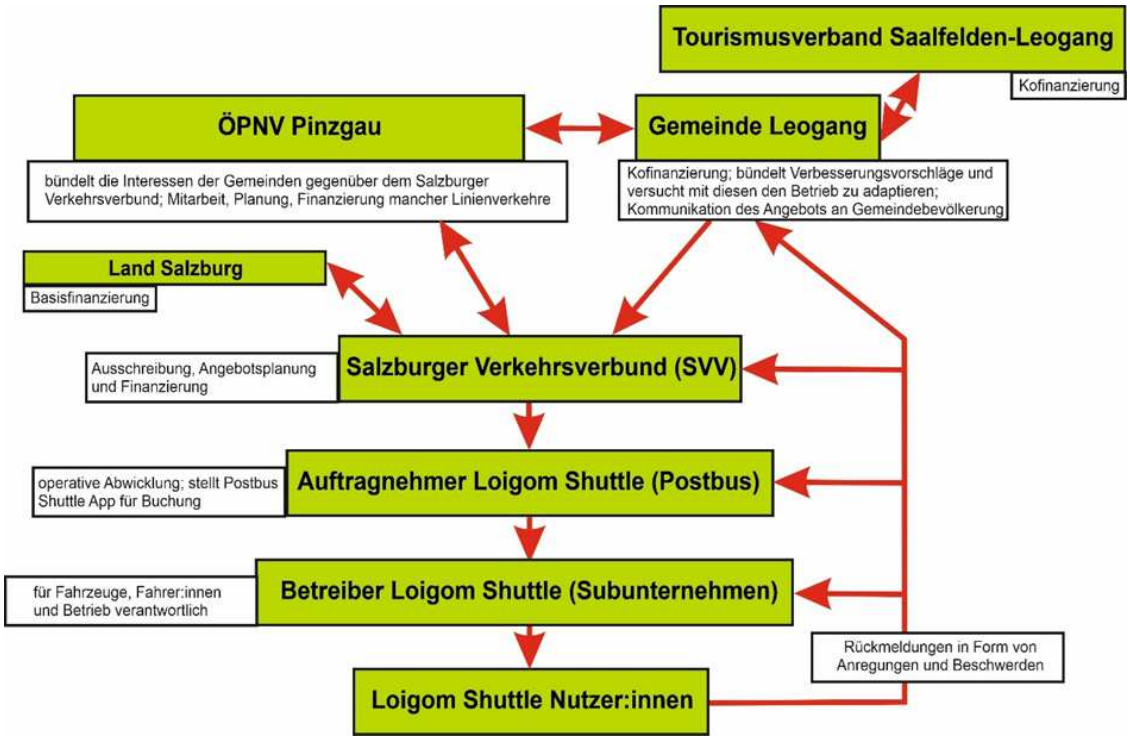

Abb. 4: Organigramm Loigom-Shuttle

Für die Durchführung des Betriebs vom Loigom Shuttle wurden zwei eigens gebrandete Elektrofahrzeuge angeschafft. Die Fahrzeuge sind 8 Sitzer-Busse der Marke Mercedes eVito. Die Disposition der Fahrten erfolgt über ein elektronisches System mit der Bezeichnung „Postbus Shuttle“. In einer App werden den Lenkerinnen und Lenkern die Navigation zum nächsten Start-/Fahrtziel mit Haltestellenname, Anzahl und Namen der zu befördernden Personen sowie gegebenenfalls einzuhebender Ticketpreis angezeigt. Das Loigom Shuttle bietet Personentransporte zwischen rund 40 festgelegten Haltestellen innerhalb des Bediengebietes nach Bedarf an. Die Fahrt erfolgt nach Verfügbarkeit zum nächstmöglichen oder zu einem festgelegten Zeitpunkt. Die Haltestellen befinden sich in der Ortsmitte der Katastralgemeinden in Leogang, bei den Bahnhöfen Leogang, Leogang-Steinberge und Hochfilzen, den Seilbahnen Asitz- und Steinbergbahn, Ausflugsorten wie dem Parkplatz Ullachtal für Wanderungen und dem Schaubergwerk sowie in weiteren kleineren Siedlungsgebieten. Fahrten von/zu einer spezifischen Adresse sind nicht möglich. Buchungen entlang der Route des Linienbusses 690 sind nur als Taktverstärker möglich, somit kann ein halbstündiger Takt auf der Talachse realisiert werden. Durch den Betriebsbeginn des Loigom Shuttles Montag-Freitag um 8:30 und den Betrieb eines eigenen Schulbusses, sind Schülerinnen und Schüler für den Loigom-Shuttle keine Zielgruppe. Das Loigom-Shuttle hat keinen festgelegten Fahrplan, die Haltestellen werden nur angefahren, wenn Fahrten vorab von oder zu diesen gebucht wurden. Ohne Vorbestellung ist somit keine Mitfahrt möglich. Die Vorbestellzeit beläuft sich auf 30 Minuten, jedoch sind auch spontane Buchungen möglich, sofern die Shuttles nicht belegt sind. Die Abholzeit welche nach einer Buchung mitgeteilt wird, stellt einen Richtwert dar und kann um einige Minuten variieren.

Das Loigom Shuttle verkehrt täglich zu den folgenden Zeiten:

- Montag bis Freitag: 08:30 bis 11:30 Uhr und 12:30 bis 19:30 Uhr
- Samstag, Sonn- und Feiertag: 08:00 bis 18:00 Uhr

Das Loigom-Shuttle ist in das Tarifsystem des SVV (Salzburger Verkehrsverbund) inkludiert. Regional gültige Tickets, wie beispielsweise das KlimaTicket Salzburg (CLASSIC, CLASSIC PLUS, SENIOR | EDELWEISS, U26, SPEZIAL, SEMESTER), das KlimaTicket Österreich sowie die (SUPER) s'COOL-CARD und die myRegio FerienCARD werden anerkannt und ermöglichen die Mitfahrt ohne weitere Aufzahlung. Ebenso wird für Urlaubsgäste die Saalfelden-Leogang Card als Mobilitätskarte Pinzgau anerkannt und ermöglicht öffentliche Mobilität in Leogang und im ganzen Pinzgau ohne Aufpreis. Ein Gemeindeticket (Einzelfahrschein) für eine Fahrt mit dem Loigom Shuttle kann direkt im Bus erworben werden und kostete zum Erhebungszeitraum 1,00 €. Abseits des Aktionszeitraumes von Anfang 2023 bis 9. Dezember 2023, in welchem die Einzelfahrscheine als Gemeindeticket ermäßigt sind, kosten diese 2,20 €, wie ein Fahrschein für eine Zone im Verbundraum. Kinder unter 6 Jahren fahren kostenlos.

4 BEFRAGUNG DER NUTZERINNEN UND NUTZER SOWIE NICHT-NUTZERINNEN UND NICHT-NUTZER

In jedem Bedienungsgebiet wurde eine Befragung der Nutzerinnen und Nutzer sowie Nicht-Nutzerinnen und Nicht-Nutzer durchgeführt, beim W3-Shuttle zwei zu verschiedenen Jahreszeiten. Die Befragung ergab an gültigen Datensätzen: W3-Shuttle: Welle 1: n=227 (September 2021) - W3-Shuttle: Welle 2: n=238 (Februar 2022); Walsiebus: n=198 (Februar 2022) und Loigom-Shuttle: n=248 (Juli 2023). Es wurde eine Papier und eine Online-Version angeboten, jeweils mit unterschiedlichen Versionen für Einheimische und für Touristen/Besucher (letztere auch in englischer Sprache). Es war möglich, den Fragebogen auf Papier selbst verwaltet (Verteilung an mehreren Punkten im Bedienungsgebiet, als Online-Version (Web-Link über QR-Code) oder als persönliches Interviews vor Ort durchzuführen. Die Rekrutierung fand vor Ort an gut frequentierten Punkten, in den Fahrzeugen der Bedarfsverkehre, in Schulen, im medizinischen Zentrum, in sozialen Medien, per E-Mail-Versand, mittels Papierfragebögen, die an unterschiedlichen Orten bereitlagen, statt. Für die ausgefüllten Papierfragebögen wurden mehrere Rückgabemöglichkeiten angeboten, zumeist an den Punkten, wo die Fragebögen auflagen, am Gemeindeamt, bei den Shuttle-Fahrerinnen nud Schuttle-Fahrern oder direkt beim Interview-Personal.

4.1 Wegezwecke der Fahrgäste

Abbildung 5 zeigt die Verteilung der Wegezwecke der Fahrten mit den Shuttles. Beim Walsie-Bus verteilen sich die Wegzwecke der Fahrten vielfältiger als bei den anderen Shuttles.

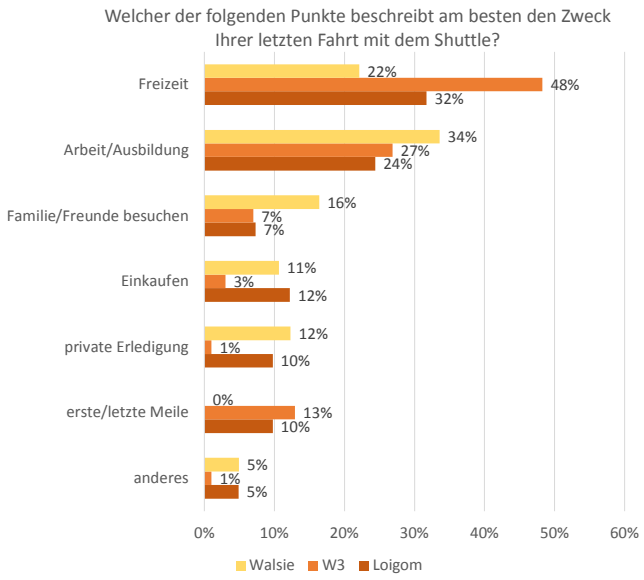

Abb. 5: Verteilung der Fahrtzwecke von Fahrten mit dem Shuttle (Befragung 2021/22 W3-Shuttle, 2022 Walsie-Bus, 2023 Loigom-Shuttle)

22 % der Befragten nutzen den Walsie-Bus für Freizeitaktivitäten, 34 % für Arbeits- oder Ausbildungswege (zusammengesetzt aus 17 % für die Arbeit und 17 % für Ausbildungszwecke), 16 % um Familie/Freunde zu besuchen und 12 % für private Erledigungen (z. B. Arzt, Behörde, Frisör) und 11 % zum Einkaufen. Im Gegensatz dazu ist der Anteil der Freizeitwege beim W3-Shuttle dominant, etwa die Hälfte (48 %) der Befragten verwendete das Shuttle zum Erreichen und/oder Verlassen von Freizeitzwecken (24 % für Wanderungen oder Wintersport und 24 % für andere Freizeitaktivitäten). 27 % für Arbeits- oder Ausbildungswege (zusammengesetzt aus 16 % für die Arbeit und 11 % für Ausbildungszwecke). Zusätzlich zu den Freizeitwegen wird mit einem Anteil von 13 % der Fahrten das Shuttle als erster oder letzter Teil einer (Fern-)Reise benützt (erste/letzte Meile). An diesen Ergebnissen ist deutlich die Relevanz des Angebots für den Freizeitbereich zu erkennen. Die Zwecke Einkaufen und private Erledigungen spielen beim W3-Shuttle kaum eine Rolle. Das Loigom Shuttle liegt funktional zwischen den beiden anderen Bedarfsverkehren. Der Anteil der Freizeitwegen ist mit 32 % ist zwar ebenfalls am höchsten, jedoch weniger dominant als beim W3-Shuttle. Für weitere 10 % wird das Shuttle als erster oder letzter Teil einer (Fern-)Reise benützt (erste/letzte Meile). Etwa ein Viertel (24 %) der Wege erfolgten zum/vom Arbeitsplatz, Ausbildungswege gab es keine. 12 % der Befragten verwendeten das Shuttle zum Einkaufen und 10 % für private Erledigungen, Anteile, die mit dem Walsie-Bus vergleichbar sind.

4.2 Alternativen zur Fahrt mit dem Shuttle

Abbildung 6 zeigt die Verteilung, ob bzw. wie der Weg zurückgelegt worden wäre, wenn es keinen Bedarfsverkehr gäbe. Beim Walsie-Bus wären 35 % der Wege mit dem privaten Pkw durchgeführt worden (19 % als Lenkerin oder Lenker und 15 % als Beifahrerin oder Beifahrer), weitere 11 % mit dem Taxi. 9 % der Befragten wären mit dem Linienbus gefahren. Es werden auch einige Wege mit nicht-motorisierten Alternativen (26 % zu Fuß gehen und 12 % (E-)Fahrrad) zurückgelegt. 8 % der Befragten hätten den Weg gar nicht zurücklegen können.

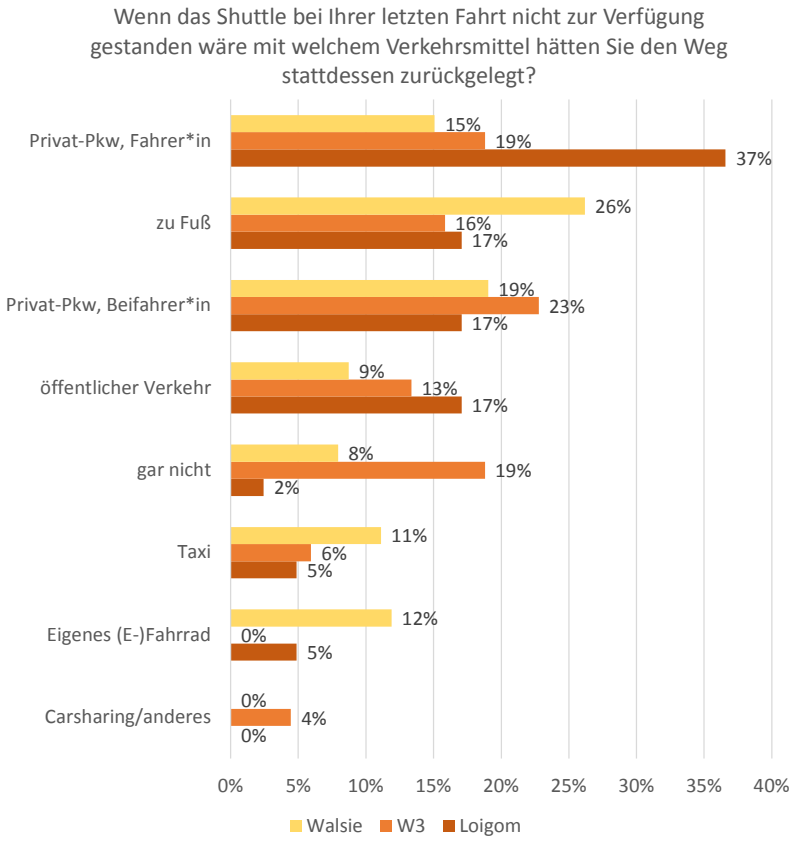

Abb. 6: Alternativen zur Fahrt mit dem Shuttle (Befragung 2021/22 W3-Shuttle, 2022 Walsie-Bus, 2023 Loigom-Shuttle)

Beim W3-Shuttle zeigt sich ein ähnliches Bild, wegen der längeren Distanzen im Bediengebiet sind die motorisierten Alternativen etwas größer (42 % privater Pkw und 13 % mit dem konventionellen öffentlichen Linienverkehr). Nicht motorisierte Verkehrsmittel kommen entsprechend weniger stark als Alternative in

Frage (16 % zu Fuß gehen, das (E-)Fahrrad wird gar nicht genannt). Beim Loigom-Shuttle sticht mit einem Wert von 37 % der hohe Anteil an privatem Pkw als Fahrerin oder Fahrer hervor, aber auch der konventionelle öffentliche Linienverkehr mit 17 %. Den Weg gar nicht ausgeführt hätten in Leogang nur 2 % der Fahrgäste. Diese Ergebnisse zeigen den Beitrag der Bedarfsverkehre zur Reduzierung der Fahrten mit dem motorisierten Individualverkehr, welche den Effekt von Fahrgästen, die ansonsten das Fahrrad benützt hätten oder zu Fuß gegangen wären, überwiegen. Hinzu kommt, dass Untersuchungen zeigen, dass ein Weg als Beifahrerin oder Beifahrer bis zu 4 Wege mit dem Pkw verursachen kann, wenn die begleitende Person den Weg nur als Bringweg zurücklegt, dazwischen nach Hause fährt und dann noch einen Abholweg zurücklegt (Klementschitz, Wurz 2010, Klementschitz, Schlemmer 2022). Ein weiterer Effekt ist der höhere Besetzungsgrad der Bedarfsverkehre als jener der individuell benutzten motorisierten Fahrzeuge, welcher den Energieeinsatz weiter reduziert.

4.3 Führerscheinbesitz

Abbildung 7 zeigt die Verteilung des Führerscheinbesitzes, unterschieden zwischen Nutzerinnen, Nutzern, Nicht-Nutzerinnen und Nicht-Nutzern der Bedarfsverkehre. Hier ist ein Unterschied zwischen den beiden Gruppen erkennbar. Während bei den Nicht-Nutzerinnen und Nicht-Nutzern je nach Region zwischen 85 % und 90 % einen Führerschein besitzen und regelmäßig einen Pkw lenken sind es bei den Nutzerinnen und Nutzern nur zwischen 70 % und 72 %. An diesen Ergebnissen lässt sich der Beitrag der Bedarfsverkehre für ein inklusives Mobilitätsangebot ablesen.

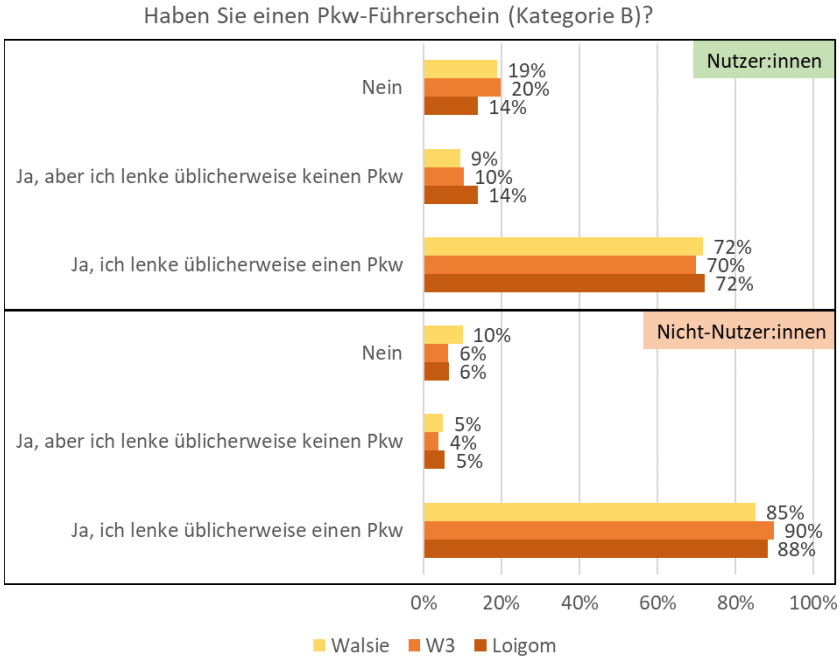

Abb. 7: Führerscheinbesitz der Nutzerinnen, Nutzer, Nichtnutzerinnen nud Nichtnutzer des Shuttles (Befragung 2021/22 W3-Shuttle, 2022 Walsie-Bus, 2023 Loigom-Shuttle)

4.4 Kenngrößen zur Zufriedenheit

Im Fragebogen wurde eine Reihe an Fragen bezüglich der Zufriedenheit der Befragten zu Themen rund um den Bedarfsverkehr gestellt (Abbildung 8). Dabei gab es auch spezifische Fragen für Nutzerinnen und Nutzer, die voraussetzen, dass man den Bedarfsverkehr bereits benützt hat. Darunter fällt die Frage, ob man das Angebot wieder benützen möchte (Zustimmung zwischen 89 % und 100 %), ob man das Angebot weiterempfehlen kann (Zustimmung zwischen 84 % und 93 %) oder wie zufrieden man mit der Benützung war (Zustimmung zwischen 66 % und 80 %). Alle erreichten Personen wurden danach gefragt, ob man mit dem Angebot vertraut ist (Zustimmung zwischen 29 % beim relativ neu etablierten Loigom-Shuttle und 66 % bzw. 76 % bei den anderen Bedarfsverkehren). Mit dem Angebot an öffentlichen Verkehrsmitteln in der Region ganz generell sind 59 % im Bedienungsgebiet des W3-Shuttles und Loigom-Shuttles sowie 49 % im Bedienungsgebiet des Walsie-Busses „zufrieden“ oder „sehr zufrieden“.

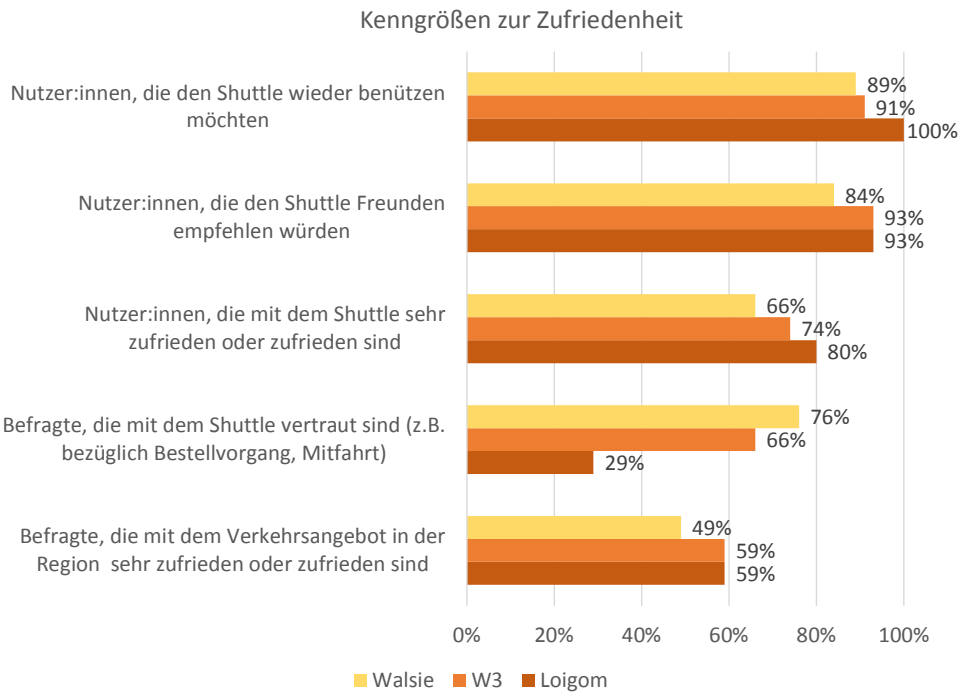

Abb. 8: Kenngrößen zur Zufriedenheit mit dem Shuttle und dem öffentlichen Verkehrsangebot (Befragung 2021/22 W3-Shuttle, 2022 Walsie-Bus, 2023 Loigom-Shuttle)

4.5 Unterschiede zwischen Nutzerinnen und Nutzern sowie Nicht-Nutzerinnen und Nicht-Nutzern

In diesem Abschnitt drei Auswertungen, unterschieden nach den Antworten der Nutzerinnen, Nutzer, Nicht-Nutzerinnen und Nicht-Nutzer. Abbildung 9 zeigt die Antworten auf der Frage der Wichtigkeit des Angebots in der Region Leogang (Loigom-Shuttle).

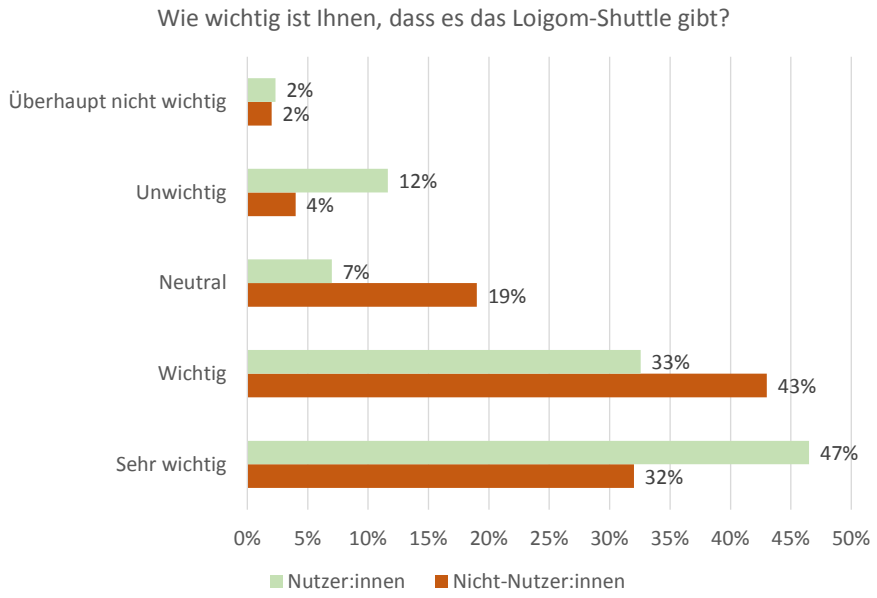

Abbildung 9: Wie wichtig ist es Ihnen, dass es das Loigom-Shuttle gibt? Nutzerinnen und Nutzer sowie Nicht-Nutzerinnen und Nicht-Nutzer (Befragung 2023 Loigom-Shuttle)

Wie erwartbar ist die Bewertung der Wichtigkeit des Angebots bei den Nutzerinnen und Nutzern generell höher als bei den Nicht-Nutzerinnen und Nicht-Nutzern. Aber auch den Nicht-Nutzerinnen und Nicht-Nutzern ist das Angebot wichtig (Optionsnachfrage), so unterscheiden sich die Zustimmungswerte für „wichtig“ und „sehr wichtig“ zusammengenommen nur geringfügig (80 % bei Nutzerinnen und Nutzern und 75 % bei Nicht-Nutzerinnen und Nicht-Nutzern). Dies ist aus zwei Gründen nachvollziehbar. Einerseits kann es ja auch bei den Nicht-Nutzerinnen und Nicht-Nutzern vorkommen, auf öffentliche Verkehrsmittel

angewiesen zu sein, und hier bietet das Loigom-Shuttle für die erste und letzte Meile sowie für den Binnenverkehr in der Gemeinde einen wichtigen Beitrag. Andererseits profitieren auch Nicht-Nutzerinnen und Nicht-Nutzer von dem Angebot, wenn Personen das Loigom-Shuttle nutzen können und nicht darauf angewiesen sind, dass diese gegebenenfalls von einem selbst transportiert werden müssten (z. B. eigene betagte Eltern, betagte Nachbarn oder eigene Kinder). Eine ähnliche Auswertung, in diesem Fall für die Region Wals-Siezenheim, ist die Frage nach der generellen Zufriedenheit mit dem Mobilitätsangebot im öffentlichen Personennahverkehr in der Gemeinde (Abbildung 10). Die Frage schließt neben dem Walsie-Bus auch bewusst andere Verkehrsmittel, wie den Stadtbus und den Regionalbus im Linienverkehr mit ein. Dabei wird deutlich, dass die Nutzerinnen und Nutzer des Walsie-Busses sowohl zufriedener sind, als auch unzufriedener sind als die Nichtnutzerinnen und Nichtnutzer, bei denen die größte Gruppe einen neutralen Standpunkt einnimmt. Leider ist die Stichprobe zu klein für weitere Unterscheidungen, aber es ist für die Nicht-Nutzerinnen und Nicht-Nutzer zu folgern, dass sie eher keinen Bedarf an öffentlichem Personennahverkehr in der Gemeinde haben (und andere Verkehrsmittel bevorzugen), als dass sie aufgrund des schlechten Angebots, keine öffentlichen Personennahverkehrsmittel benützen. Mehr als die Hälfte aller Nutzerinnen und Nutzer des Walsie-Busses sind zufrieden oder sehr zufrieden mit dem Angebot in der Gemeinde (zusammen 54 %).

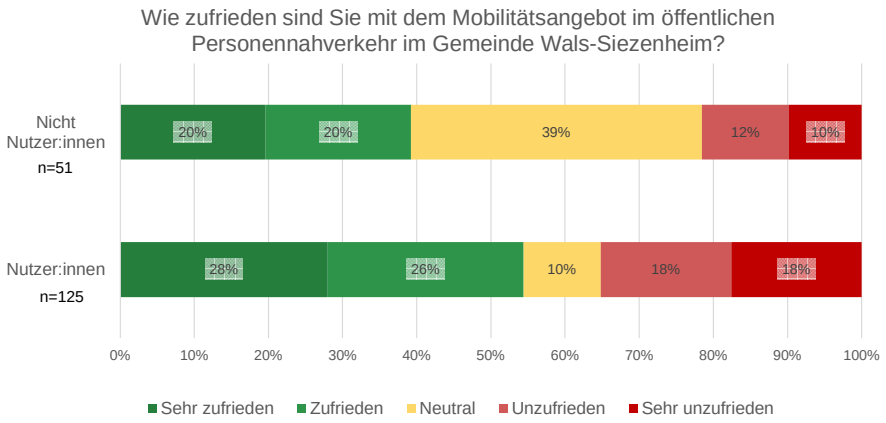

Abbildung 10: Wie zufrieden sind Sie mit dem Mobilitätsangebot im öffentlichen Personennahverkehr in der Gemeinde Wals-Siezenheim, Nutzerinnen und Nutzer sowie Nicht-Nutzerinnen und Nicht-Nutzer (Befragung 2022 Walsie-Bus)

Abbildung 11 zeigt den Zusammenhang der gewählten Verkehrsmittel für die Anreise in die Gemeinde (für Touristinnen und Touristen, Einpendlerinnen und Einpendler, Besucherinnen und Besucher) und die Benützung des W3-Shuttles in der Region Werfen/Werfenweng und Pfarrwerfen. Es ist abzulesen, dass aufgrund der Schließung der ersten/letzten Meile und einem adäquaten Mobilitätsangebot vor Ort durch den Bedarfsverkehr deutlich mehr Personen mit der Bahn anreisen (52 %) als Nichtnutzerinnen und Nichtnutzer des Angebots (6 %). Das heißt in weiterer Folge, dass sich der Bedarfsbus auch auf das Verkehrsgeschehen außerhalb der Region positiv auswirkt, weit hinein in die touristischen Quellgebiete.

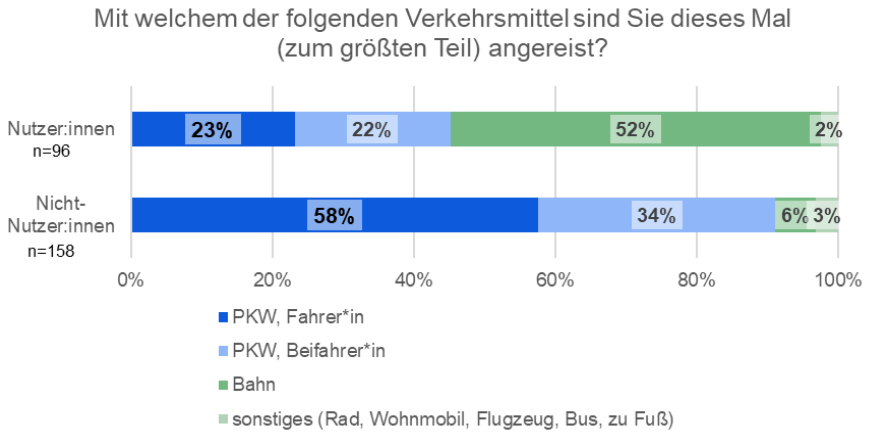

Abbildung 11: Verkehrsmittelwahl zur Anreise von Touristen und Besucherinnen und Besuchern, getrennt nach Nutzerinnen und Nutzern sowie Nichtnutzerinnen und Nichtnutzern des W3-Shuttles, Befragung 2021/22

5 STAKEHOLDERINNEN- UND STAKEHOLDER-INTERVIEWS

Im Rahmen der Studie wurden insgesamt 18 semistrukturierte vertiefte Interviews mit Stakeholdern der Bedarfsverkehre aus den Bereichen Mobilität, Tourismus und Verwaltung durchgeführt (8 Interviews W3-Shuttle, 4 Interviews Walsie-Bus und 6 Interviews Loigom Shuttle). Die Interviews behandelten Themen wie Ziele, Zielgruppen, das gewählte Betreibermodell, Erfolg und mögliches Potenzial für Weiterentwicklungen des Betriebs. Als Ziele beim W3-Shuttle wurden hohe Effizienz, die Schaffung eines Last-Mile-Services, und eine hohe Auslastung definiert. Beim Walsie-Bus hingegen stehen die Vermeidung von Leerfahrten bei einem festen Fahrplan und die hohe Flexibilität des Angebots im Mittelpunkt. Beim Loigom-Shuttle steht ebenfalls wie beim W3-Shuttle die Schaffung eines Last-Mile-Services (durch Schließung von Versorgungslücken) an oberster Stelle. Hier werden aber auch Ziele wie die Steigerung der Lebensqualität und die Identifikation mit dem Service innerhalb der Gemeinde genannt. Als Zielgruppe für den Bedarfsverkehr werden in den touristisch geprägten Regionen (W3-Shuttle und Loigom-Shuttle) zuerst Touristinnen und Touristen genannt, gefolgt von mobilitätseingeschränkten Personen, beim Loigom-Shuttle werden auch dezidiert die Einheimischen genannt. Beim Walsiebus sind es die Einheimischen, speziell ältere Personen. Die Vorzüge des gewählten Betreibermodells, das ja mit einem lokalen Taxiunternehmen als ausführender Betrieb in allen drei Regionen vergleichbar ist, werden die gute Zusammenarbeit mit dem Betreiber, dass die Fahrerinnen und Fahrer aus der Region kommen (Ortskundigkeit und lokale Wertschöpfung) und den flexiblen Einsatz der Fahrzeuge in Abstimmung auf die Nachfrage positiv hervorgehoben. Erfolg wiederum wird durchaus unterschiedlich definiert. Beim W3-Shuttle werden für einen erfolgreichen Betrieb die Zuverlässigkeit und Vertrauen bei den Kunden erwähnt, beim Walsiebus, dass der Betrieb Mobilität der Nutzerinnen und Nutzer ermöglicht und beim Loigom-Shuttle, dass es eine hohe Auslastung und hohe Passagierzahlen gibt und das Angebot niederschwellig ist (bezüglich Kosten und Buchungsvorgang). Als Potenzial für eine Weiterentwicklung des Betriebs werden beim W3-Shuttle die Schaffung eines Nachtbetriebs, kürzere Buchungsmöglichkeiten durch Online-Buchung und ein integriertes Ticketing genannt. Beim Walsie-Bus die Erweiterung des Bediengebietes, wodurch Umsteigvorgänge wegfallen würde und die laufende Anpassung der Haltepunkte (auf Basis der Wünsche (potenzieller) Nutzerinnen und Nutzer. Beim Loigom-Shuttle ist ebenfalls eine räumliche Erweiterung des Bediengebietes durch die Erweiterung nach Saalfelden (mit Anschluss an den Bahnhof und an das regionale Zentrum) an erster Stelle (auch dadurch würden Umsteigvorgänge wegfallen).

6 SCHLUSSFOLGERUNGEN

Erfolgsfaktoren sind das klare (auch finanzielle) Bekenntnis der Gemeinden (und beim W3-Shuttle und Loigom-Shuttle auch des Tourismusverbandes), die Durchführung des Betriebs durch einen professionellen Betreiber aus der Taxi/Reisebusbranche, der Einsatz von Fahrzeugen mit einer Kapazität von bis zu 8 Fahrgästen inklusive flexibler Aufstockung der Anzahl der Fahrzeuge bei Nachfragespitzen, die prinzipielle Ausklammerung des Schülerverkehrs, die Anerkennung der Fahrkarten des Verkehrsverbundes, die Abstimmung und Anbindung des Angebots an das übergeordnete Verkehrssystem und ein Betrieb an allen Tagen der Woche. Die Abgrenzung des Bediengebiets ist eine wichtige Planungsentscheidung und hat auf die Mindestzeit zwischen Bestellvorgang und Durchführung der Fahrt Einfluss. Gemeindegrenzen sind weniger wichtig als die notwendigen Fahrtzeiten innerhalb des Bediengebietes. Diese sollten daher nicht größer sein, als es eine Vorbestellzeit von 60 Minuten (besser 30 Minuten) zulässt. Die Teilung in mehrere Gebiete/Zonen ist durchaus eine Möglichkeit und wird beim W3-Shuttle und Walsie-Bus angewandt.

Im Betrieb muss alles unternommen werden, dass die (potenziellen) Fahrgäste das Vertrauen haben, dass ihrem Fahrtwunsch entsprochen wird. Nur dadurch kann eine Stammkundschaft geschaffen werden (auch indirekt, durch Empfehlung bestehender Nutzerinnen und Nutzer oder Multiplikatorinnen und Multiplikatoren, z. B. die Beherbergungsbetriebe für ihre Gäste), die einen Betrieb längerfristig rechtfertigen kann. Bedarfsverkehr werden primär für den Freizeitbereich genutzt, daher sind die Zeiten stärkster Nachfrage am Nachmittag. Bei allen Bedarfsverkehren fällt der hohe Anteil an Gelegenheitsnutzerinnen und Gelegenheitsnutzern auf, so sind die meisten Nutzerinnen und Nutzer mit Einzeltickets unterwegs. Durch die hohe Zuverlässigkeit und Flexibilität der Bedarfsverkehre sind 74 % der Nutzerinnen und Nutzer beim W3-Shuttle, 66 % beim Walsie-Bus und 80 % beim Loigom-Shuttle zufrieden oder sehr zufrieden mit dem Angebot.

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BIM and Carbon Emissions Nexus: A Way Forward for Reducing Carbon Emissions in the South African Construction Industry

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1 ABSTRACT

The construction industry in South Africa faces significant sustainability challenges due to its substantial carbon emissions. Building Information Modelling (BIM) presents a promising solution, offering substantial reductions in energy consumption, waste production, and prioritizing low-emission materials. This qualitative study, through expert interviews and case studies, explores BIM's potential in promoting sustainable construction practices. Findings indicate that BIM can achieve a 20% reduction in energy consumption, a 15% reduction in waste production, and a 10% increase in the use of low-emission materials, thereby enhancing sustainability and efficiency in the construction sector. However, the adoption of BIM is hindered by challenges such as skill shortages and resistance to change. To position South Africa as a leader in sustainability and innovation, there is a need for widespread BIM adoption through strategic initiatives that enhance BIM literacy and incentivize its implementation. Embracing BIM is crucial for the construction industry's move towards a more sustainable future, with potential for significant environmental and economic benefits.

Keywords: carbon emission, construction industry, BIM, net zero, sustainable development

2 INTRODUCTION

The construction industry is a significant contributor to global carbon emissions, with residential and commercial structures alone responsible for approximately 36% of yearly greenhouse gas emissions (Du, et al. , 2019:3697-3709). Studies have consistently highlighted the substantial impact of the construction sector on carbon emissions, with figures ranging from 36% to over 40% of total global carbon emissions (Liu, et al. , 2017:1680, Li, S., et al. , 2021a:1728, Jiang, et al. , 2019:42, Chuai, et al. , 2015:13021-13030, Li, R. and Jiang, 2017:1013). In china specifically, the construction industry is reported to consume around 40% of the world's total energy resources and account for nearly 36% of global co2 emissions (Jiang, et al. , 2019:42). Furthermore, the construction industry in china has been noted to play a crucial role in the country's efforts to achieve carbon neutrality by (Chi, et al. , 2021:1876).

Research has shown that the construction industry not only consumes a significant amount of energy but also emits large volumes of carbon dioxide (Paik, 2019:3571). The industry's carbon emissions are a matter of concern globally, with scholars emphasizing the need for the sector to reduce its carbon footprint (Jackson and Kaesehage, 2020:2973-2983). Efforts to mitigate carbon emissions in the construction industry are crucial, especially considering that indirect carbon emissions from construction activities can make up a substantial portion of total emissions (Li, T., et al. , 2022:).

Various studies have explored different aspects of carbon emissions in the construction industry, including spatial analyses, benefit evaluations of energy-saving practices, and forecasting models for carbon emissions (Du, et al. , 2018a:1220, Dai, et al. , 2022a:, Pu, et al. , 2022:4950). The urgency of addressing carbon emissions in the construction industry is evident, with projections indicating significant future emissions if mitigation measures are not implemented (Guo and Yin, 2022:).

South Africa is addressing the challenge of balancing enhanced service delivery with environmental sustainability by adopting Building Information Modelling (BIM). BIM offers opportunities for reducing emissions through cooperation, energy efficiency, and waste reduction. The country faces challenges in transitioning from a high-carbon energy system to a more sustainable one, including securing electricity

supply and reducing greenhouse gas emissions. Sustainability is a growing concept in South Africa, but its unique demographic profile and historical context pose barriers to effective climate action. South Africa is one of the highest CO_2 emitters globally, and its reliance on coal-fired power plants contributes significantly to its carbon footprint. To achieve sustainable development goals, South Africa must decouple economic growth

The South African industry has been adopting and applying BIM in the past few debades but the extent to which this innovation has contributed to the reduction of carbon emissions is not yet clear. Hence, this paper discusses the utilisation of BIM by South African construction enterprises and the levels of carbon-based emissions over the years. Specifically, the paper reviews relevant existing literature on the efficacy of BIM on waste reduction and material selection in reducing energy consumption current state of carbon emissions in the South African construction industry.

This research focuses on the utilization of building information modelling (bim) by south african construction enterprises to mitigate carbon-based emissions. The study aims to assess the current state of carbon emissions in the industry, examine the efficacy of bim in reducing energy consumption and waste, analyze its impact on material selection and building longevity, and explore stakeholder engagement and collaboration facilitated by bim. The significance of this research lies in its potential to inform sustainable practices, guide policy development, and enhance environmental stewardship in the south african construction industry. By exploring how bim influences energy consumption, waste reduction, and stakeholder collaboration, this study aims to position south africa as a leader in sustainable construction, contributing to global eco-friendly building practices. The findings underscore the importance of implementing sustainable practices and technologies in the construction industry to curb its environmental impact and contribute to overall climate change mitigation efforts.

The paper discusses the carbon emissions in the global and South African construction industry and the potential of Building Information Modelling (BIM) to mitigate them. It reviews literature, examines BIM's impact on energy consumption, waste, material selection, and stakeholder engagement. The study uses qualitative research methods and provides recommendations for future research and industry practices, emphasizing BIM's importance in sustainable construction.

3 CONCEPTUAL SYNOPSIS

The construction industry plays a pivotal role in global carbon emissions, with the sector responsible for a significant portion of greenhouse gas emissions. In South Africa, the challenge is to balance enhanced service delivery with environmental sustainability. Building Information Modelling (BIM) emerges as a crucial tool in this endeavor, offering opportunities for reducing emissions through enhanced cooperation, energy efficiency, and waste reduction. This study adopts an interpretivist philosophical orientation and an exploratory research strategy with a qualitative approach, aiming to scrutinize the utilization of BIM by South African construction enterprises to mitigate carbon-based emissions. The research objectives include assessing the current state of carbon emissions, examining the efficacy of BIM in reducing energy consumption and waste, analyzing its impact on material selection and building longevity, and exploring stakeholder engagement facilitated by BIM.

4 BACKGROUND

In recent decades, the building sector has experienced substantial technical progress, focusing on expanding efficiency, minimising expenses, and promoting sustainability. One of the most transformative technologies in this sector is building information modelling (BIM), which has revolutionised the way construction projects are planned, designed, and managed.

BIM is a computerised model that accurately depicts a structure’s physical and functional aspects. It allows different parties involved in a project to easily exchange information and work together efficiently from start to finish. It facilitates improved decision-making, reduces errors and conflicts, and enhances overall project performance. The evolution of construction technology, as summarised in the table below, highlights the increasing importance of digital tools like BIM in the industry:

Building Information Modelling (BIM) is a crucial tool in the construction industry, enhancing service delivery and promoting environmental sustainability. It facilitates creating, managing, and utilising digital

representations of places' physical and functional characteristics. BIM's impact extends beyond visualisation, enabling a collaborative environment for architects, engineers, contractors, and clients to work together. This collaboration facilitates the early detection of possible faults during the design process, decreasing the probability of expensive modifications and delays.

YEAR	TECHNOLOGY	IMPACT
2000	Building Information Modeling (BIM)	Improved collaboration and project visualisation
2005	Drones	Enhanced surveying, monitoring, and inspections
2010	3D Printing	Prototyping, customised components, and cost-efficiency
2015	Augmented Reality	On-site visualisation, training, and safety
2018	Internet of Things	Real-time monitoring, predictive maintenance
2020	Robotics and Automation	Increased efficiency and reduced labor costs
2022	Artificial Intelligence	Project planning, risk analysis, and decision-making
2024	Quantum Computing	Advanced simulations and complex problem-solving

BIM's ability to integrate various data types, including geometrical, spatial, and environmental information, allows for more informed decision-making. Energy modelling tools integrated with BIM can provide insights into a building's energy consumption, enabling the design of more energy-efficient buildings. Emerging technologies like augmented reality, virtual reality, and the Internet of Things (IoT) also integrate BIM, enriching the model and enabling predictive maintenance and energy management. BIM represents a significant technological advancement in the construction industry, driving sustainability by enabling more efficient design, construction, and operation of buildings.

5 LITERATURE REVIEW

Carbon Emissions: A Global and South African Context

Construction activities contribute significantly to global carbon emissions, accounting for 39%. In South Africa, carbon emissions from construction increased by 1.5% to 2% in 2022, representing 13% to 36% of the allocated carbon budget (Chen, et al. , 2023:1627-1657, Li, S., et al. , 2021b:1728).

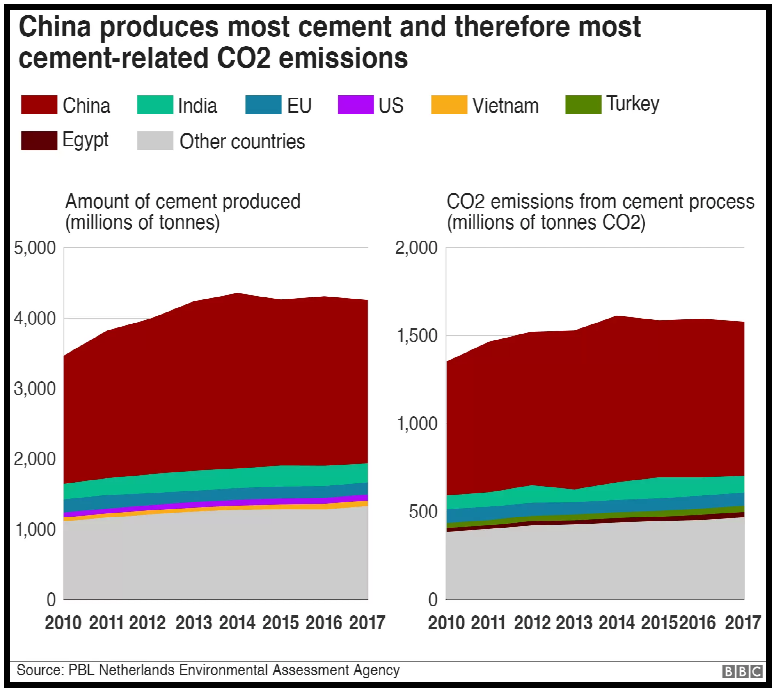

Figure 1: Cement Related CO2 emissions (Source: BBC, 2018)

The construction sector is a significant energy user, accounting for more than 40% of worldwide energy consumption and 36% of global carbon emissions. Research shows that carbon emissions come from direct and indirect sources, mainly upstream industries, during the construction material preparation phase. Sustainable construction practices are crucial for achieving sustainability goals, and accurate estimation and

mitigation strategies are essential (Mohebbi, et al. , 2023:355-375, Yang, et al. , 2022:e0264579, Joseph and Mustaffa, 2023:1271-1299, Willhelm Abeydeera, et al. , 2019:3030, Du, et al. , 2018b:1220).

The impact of construction extends beyond direct construction phases, as expansion of construction land encroaches on carbon sink areas like farmlands and forests, affecting carbon sequestration capacities and overall emissions. Strategies for spatial analysis of carbon emissions from human-social systems are proposed to manage human carbon emissions effectively.(Dong, 2023:, Crawford, 2022:, Dai, et al. , 2022b:, Mohebbi, et al. , 2023:355-375, Yang, et al. , 2022:e0264579, Joseph and Mustaffa, 2023:1271-1299, Willhelm Abeydeera, et al. , 2019:3030).

6 METHODOLOGY

The interpretivism as a philosophical orientation informed an exploratory research strategy and qualitative research approach that were adopted and applied in the study. Data was collected form a variety of secondary sources, such as books, journals, theses, and governemnts documents. Specifically, scholarly materials, on the application of BIM in the South African construction industry were compiled. Data was analyzed by categorizing common themes emerging from literature sources that relate to the application of BIM in the construction industry, how it has been contributing to efficiency, reducing carbon emissions, and promoting sustainable practices.

7 RESULTS AND DISCUSSION (DECREASING CARBON EMISSIONS THROUGH THE HELP OF BIM)

South Africa has been working to reduce its carbon emissions, particularly in the construction sector, which has significantly impacted the country's high energy demand. Building Information Modelling (BIM) has demonstrated its efficacy in mitigating these emissions by accurately simulating building performance, reducing energy usage by over 20% compared to conventional approaches. BIM also helps minimise waste production, with construction waste decreasing to less than 15% due to its use in projects like Johannesburg and Pretoria.

BIM also helps ensure sustainable buildings by promoting better choices and reducing demolitions.

A case study from Bloemfontein showed that BIM reduced 20% of emissions through demolition and reconstructive Stakeholder Engagement and Collaboration. The government's 2.3 trillion investment plan has supported sustainability by promoting the adoption of technologies to reduce carbon emissions in the construction industry.

This study examined the adoption of Building Information Modelling (BIM) in South Africa's construction industry, focusing on its impact on reducing carbon-based emissions, efficiency, and sustainable practices. It analyzed qualitative data from secondary sources and highlighteed key themes and yielded five (5) resultd summerized hereunder.

Result No	Result Name	Result Description
Result 1	BIM Adoption	BIM adoption is the integration of Building Information Modelling (BIM) technology into an organization's workflows, operations, and culture, particularly in AECO sectors, facilitating knowledge sharing throughout a building's lifecycle.
Result 2	Energy Efficiency	How BIM contributes to designing energy-efficient buildings, leading to reduced energy consumption and lower carbon emissions.
Result 3	Sustainable Materials	The role of BIM in selecting materials with lower carbon footprints and promoting sustainable construction practices.
Result 4	Waste Reduction	The impact of BIM on minimising construction waste through efficient planning and management.
Result 5	Stakeholder Collaboration	The influence of BIM on enhancing collaboration among stakeholders, leading to better decision-making and sustainable outcomes

The research aims to investigate the relationship between these results and their collective impact on reducing carbon emissions in the construction industry. By exploring the potential of BIM in addressing environmental challenges, the study seeks to contribute to developing sustainable construction practices in South Africa.

Collaboration among architects, engineers, construction experts, and others has led to increased cooperation and the development of best practices. Funding training and education facilities led by South African construction professionals have also been instrumental in promoting the use of BIM to reduce emissions. Universities and technical institutions have also developed programs and seminars to promote sustainable building practices and the growth of environmentally-focused professionals.

8 CONCLUSION

The study demonstrates the significant impact of Building Information Modeling (BIM) technology on South Africa's construction industry, reducing carbon emissions, improving waste management, and promoting sustainable practices. It recommends integrating stakeholders and investing in education and training to foster a more eco-efficient future, thereby making South Africa a leader in sustainability and innovation.

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🏆 *reviewed paper*

Chronicles of Peri-Urban Expansion in Small Rural Towns: a Comprehensive Study of Makhado Biaba's Built-Up Areas from 1995 to 2022

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1 ABSTRACT

Over the past few decades, the phenomenon of peri-urban expansion has emerged in South Africa as a significant and complex challenge, particularly for small towns across rural municipalities. Traditionally characterized by their rural economies and close-knit communities, these towns now find themselves at the crossroads of urbanization, grappling with the complex implications of expanding urban influence. This paper investigates the dynamic changes in the Makhado Biaba town's spatial landscape post-apartheid era, spanning from 1995 to 2022. The work adopted a mixed methods research approach, which employs both quantitative and qualitative research approaches. Google Earth Engine (GEE) was used for supervised classification to evaluate the Support Vector Machine (SVM) algorithms, using Landsat-8 images. Questionnaires were administered to collect qualitative and quantitative data and key informative interviews were conducted to gather qualitative data. Statistical Package for Social Sciences (SPSS) was used to analyse quantitative statistical data and thematic analysis was employed for qualitative data analysis. Findings reveal that the land cover of the build-up area increased from 1443.0 HA in 1995 to 1936.0 HA in 2011 and further increased to 2279.0 HA in 2022. This significant increase highlights the visible increase of built-up areas, attributed to the rapid growth in population, which drives the escalating demand for land to accommodate housing and infrastructure needs. Leading to the encroachment of urban settlements into neighbouring rural areas, causing the convergence of urban and rural settlements. Due to the communal tenure system, it is frequently difficult for the municipality to facilitate the demarcation of sites and commercial development on tribal land. Limited authority over such areas, makes it difficult for rural municipalities to control growth and align development with the goals of the municipal bylaws. Ultimately, the study recommends sustainable urban development strategies in mitigating adverse effects on the environment and community well-being. Thus, there is a need to reconcile conflicting By-laws to create a cohesive land management framework that accommodates both traditional practices and modern spatial planning and land use management by-laws. There is also a need to formulate peri-urban expansion strategies tailored to rural contexts by considering local needs, minimizing environmental impact, and actively involving the community in the planning process.

Keywords: sustainable development, land use, peri-urban, accuracy assessments, small rural towns

2 INTRODUCTION

The phenomenon of peri-urban expansion is a globally recognized trend that is significantly reshaping the landscapes of small rural towns. The small rural Makhado Biaba Town, situated in the heart of Limpopo, stands as a poignant example of this transformative process. Over the past few decades, the town has experienced a surge in spatial development, blurring the lines between rural and urban spaces. The expansion of infrastructure and changing land use patterns have all contributed to the gradual spatial evolution of Makhado Biaba Town into a dynamic peri-urban entity. Understanding the nuances of peri-urban expansion is imperative not only for Makhado Biaba but also for countless similar towns grappling with similar transitions worldwide (Jain, Sikder and Korzhenevych, 2023).

The term peri-urban is complex and has been defined differently by different scholars. It has been described as a location, process, or concept. Peri-urban is the zone between rural and urban activities as a concept; as a process, it is the gradual transformation of rural areas as they acquire more urban characteristics; and as a

location, it is the region between rural and urban zones (Mortoja and Yigitcanlar, 2021; Douglas, 2006). Peri urban often refer to a compound of rural and urban features in transition which are characterized by unregulated land uses and multiple land administration structures (Hungwe, 2014; Ingwani, 2021) without a fixed definition. Additional to the conventional rural and urban spaces, the peri-urban areas may be conceptualized as a "third space" (Ingwani & Gumbo, 2016). Currently, the peri-urban expansion of Makhado Biaba Town seems to be inevitable. This expansion not only reshaped the town's physical footprint but also redefined its socio-economic dynamics, engendering new patterns of land use and community life. Furthermore, peri-urban expansion is likely to continue for as long as the agricultural land is available in the vicinity. In many small rural towns of South Africa, agricultural activities are slowly diminishing because of the insurgence of a cash economy and off-farm income streams. According to Ingwani (2019), similar situations were observed in Domboshava and Masvingo in Zimbabwe, where peri-urban livelihoods are changing because of the outward spatial expansion of the peri-urban zone. As the peri-urban zones extend into the hinterland, the existing peri-urban area is pushed out further and replaced by a new frontier usually characterized by inhabited land (Hoggart, 2016). Thus, through such expansion, rural areas assume the character of cities. Small rural towns of South Africa are service centers located in the rural areas on the bottom rung of the ladder that classifies and defines cities. They are surrounded by villages dominated by agricultural production (Temudo, Cabral and Talhinhas, 2020) Currently, a significant number of South Africa's population live in small rural towns which experience a considerable inflow of migrants.

The study of peri-urban expansion in Makhado Biaba Town is situated within a broader scholarly discourse on urbanisation, regional development, and sustainable planning. While urbanization has traditionally been associated with large metropolitan areas, the increasing prevalence of peri-urban growth in small towns presents unique challenges and opportunities (Salvia, Halbac-Cotoara-Zamfir, Cividino, Salvati, and Quaranta, 2020). By delving into the specifics of Makhado Biaba's experience, this study contributes to a more nuanced understanding of urban dynamics at the rural-urban interface and also seeks to bridge the gap between academic inquiry and practical policymaking. By offering insights gleaned from empirical analysis and spatial analysis, it aims to inform decision-makers, planners, and stakeholders involved in shaping the future trajectory of Makhado Biaba Town. In doing so, it aspires to foster sustainable development practices that reconcile the imperatives of growth with the preservation of Makhado Biaba's Town cultural and environmental heritage.

3 CONCEPTUAL SYNOPSIS

The Theory of Change (ToC) provides a framework for understanding how interventions or actions lead to desired outcomes (Yang, van Timmeren and Tillie ,2023). In the context of peri-urban expansion in small rural towns like Makhado Biaba, the ToC can help elucidate the interconnected factors driving this phenomenon and its potential impacts. One key aspect of the ToC is recognising the drivers of change, which in this case include demographic shifts, spatial dynamics, and infrastructure development (Waisbord ,2020). Consequently, as rural areas experience population growth and economic transformation, there is increased pressure on land and resources, leading to the expansion of peri-urban areas. Additionally, investments in infrastructure, such as roads and utilities, may facilitate this expansion by improving accessibility to previously remote areas, thereby attracting both residents and businesses.

Furthermore, the theory of change highlights the pathways through which interventions or policies can influence outcomes (Taplin, Clark, Collins and Colby,2013). Interventions aimed at land use planning, governance structures, and economic development can play a crucial role like implementing zoning regulations and land use planning strategies to help manage the spatial growth of peri-urban areas, balancing the need for urban development with the preservation of agricultural land and natural resources. Similarly, promoting inclusive governance structures that involve both traditional leadership and local municipalities can enhance coordination and decision-making processes, ensuring that peri-urban expansion is guided by sustainable development principles and addresses the needs of all stakeholders. Peri-urban areas are transitional areas experiencing rapid transformations as a result of demands from development and urban growth. ToC provides an organized way to think about how deliberate activities and planned interventions can result in improvements in these areas (Meyer, Louder, and Nicolas, 2022). Planners can use it to map the progression of events and effects, guiding decision-making toward sustainable and balanced development.

4 METHODOLOGY

This study adopted the case study research design where Makhado Biaba town in South Africa was studied. The work applied a mixed method research approach and also utilized high-resolution satellite sensors like Landsat 5 TM and Landsat 8 OLI to detect changes in Land Use Land Cover (LULC) (Jamal & Ahmad, 2020; Jamali, 2019). Non-Parametric Machine Learning classifier like Support Vector provided accurate LULC classification results. Images were uploaded through GEE coding each year, with atmospheric correction and ready for classification using Support Vector Machine (SVM) algorithms (Foody & Mathur, 2004). Ground-based fieldwork was conducted, with 100 sample sizes per class for bare soil and built-up areas. Systematic random sampling was applied for each class, with 70% training samples and 30% validation testing. Ground truth data collection for land use and land cover (LULC) change in Makhado Biaba town involved systematic random sampling, stratified sampling, field surveys and thorough validation procedures. The collected information was cross-checked and verified through multiple visits and comparisons with existing data sources to ensure the reliability and representativeness of the final sample. Questionnaires survey and key informative interviews was applied as primary data collection methods, and SPSS and thematic analysis were employed for data analysis respectively (Alshenqeeti, 2014). This work also conducted interviews and questionnaires. Key informant interviews were conducted with key informant personnel from Makhado Local Municipality and the Traditional leaders. Questionnaires were distributed to people who reside in Makhado Biaba and five surrounding villages. Interviews with the municipal officials were unstructured and the interviews were conducted physically, and the questioners conducted with residents were structured. Random sampling was used to select households that were targeted for participating in the survey. SPSS and thematic analysis were also employed for data analysis respectively.

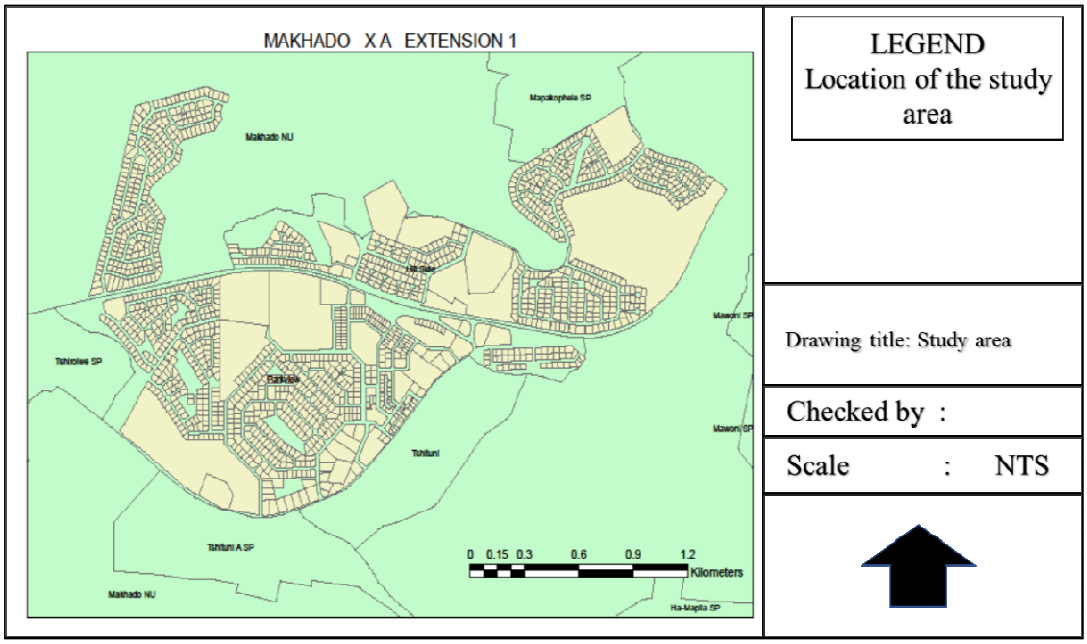

Figure 1: Location of the study area (Makhado Biaba town and surrounding villages). Source: Modified by authors, 2023

5 STUDY AREA

Makhado Biaba used to be one of the four districts in the former Republic of Venda, along with Vuwani, Mutale and Thohoyandou (Makhado Municipality IDP, 2018/19). The majority of the surrounding Villages in Makhado Biaba town survive primarily on subsistence farming and livestock keeping, with vegetables being sold when deemed necessary and appropriate in town. Makhado Biaba Town consist of nine villages, and five villages were selected purposively and conveniently to participate in the research (Makhado IDP, 2018/19). Land administration, of the peri-urban villages of Makhado Biaba town are administered by local traditional leadership, chiefs, and village headman's. They act as the central institute in land governance, specifically for allocating land tenure rights in terms of a Permission to Occupy (PTO) on behalf of governmental bodies like the state and local municipalities (Ingwani, 2021). Makhado Biaba is generally rocky and can be described as a mountainous area in local terms. Like many former R293 towns, Makhado Biaba town was established in terms of the Proclamation 45 of 1990. The Proclamation R293 is still in use

with the Town Planning Scheme. This implies that R293 still exists in Makhado Biaba town as it has not been repealed, and the town is also within the Scheme and Ordinance areas. Demarcation of sites is no longer applicable in Makhado Biaba town. Sites are being subdivided in terms of section 92 of the Town Planning and Township's Ordinance, 15 of 1986, Makhado Municipality Spatial Planning, Land Development and Land Use Management By-Law of 2016 and Makhado Land Use Management Scheme of 2009. However, in the surrounding villages (peri-urban) demarcation of sites exists through chiefs.

Figure 1 shows Makhado Biaba town and the surrounding villages, which falls under the Makhado local municipality which is Category B.

6 FINDINGS

This section presents the findings and discussion of the study analyzing Landsat 5 TM and Landsat 8 OLI data, revealing quantification and prognosis results for the SVM classifier, providing a comprehensive understanding of LULC detection in Makhado Biaba Town over 27 years.

6.1 Land Cover/Land Use Classification

The study used Landsat's TCC to digitize training sites, generate imagery from Google Earth Engine, and classify images using the South African classification system. SVM was used for the classification. Using Landsat images, Google Earth Engine, and remote sensing technology allows to access and analyze a large amount of spatial information over a long period of time, providing a comprehensive view of the changes in Makhado Biaba town. Landscape Metrix analysis, including confusion matrix and support vector machine algorithm, allows for the accurate classification and quantification of land cover and land use changes over time. Overall accuracy, producers and user's accuracy, as well as kappa statistics, provide a quantitative measure of the accuracy of our analysis. Additionally, patch density, greatest patch area, mean patch area, number of patches, and landscape proportion provide important metrics for understanding the spatial patterns and distribution of land cover changes in Makhado Biaba town. Ultimately, these methods and tools are essential for accurately mapping and assessing the spatial changes in the town from the post-apartheid era (1995) to the present day (2022). In order to map spatial changes in Makhado Biaba town post-apartheid era from 1995 to 2022, it is necessary to use Landsat images, Google Earth Engine, and remote sensing technology to access historical and current satellite data. Landscape Metrix analysis, confusion matrix, and support vector machine algorithm are important tools for processing and analyzing the satellite imagery to accurately identify and classify changes in land cover over time. Metrics such as overall accuracy, producers and users accuracy, as well as Kappa statistics, are essential for evaluating the accuracy of the land cover classification. Patch density, greatest patch area, mean patch area, number of patches, and landscape proportion are used to quantify the spatial patterns and fragmentation of land cover changes. Additionally, it is important to assess the size and distribution of different land cover types in order to understand the overall landscape changes in Makhado Biaba town over the specified time period. Therefore, the integration of these tools and techniques is crucial for effectively mapping and monitoring the spatial changes in the town over the post-apartheid era.

6.2 Results For Quantifying Land Use Land Cover Change Using Landscape Metrics/Accuracy Assessments

This research focuses on monitoring and detecting changes in land use using landscape metrics, including compositional and configurational metrics. The study uses Patch Density (PD), greatest patch area (GPA), mean patch area (MPA), and number of patches (NP) types of landscape metrics. The "number of patches" (NUMP) is expected to increase with nucleated urban development, but decreases significantly when urban patches combine into a single homogenous patch. Total Edge (TE) determines the overall perimeter of all urban patches, while the "mean patch edge" (MPE) refers to the typical amount of edge found in each patch. Later, landscape metrics for each map from 2008 to 2022 were calculated using the Landscape Metrics Plugin on QGIS, a product of the FRAGSTATS software. These metrics were chosen to calculate six main characteristics of land use land cover areas: absolute size, relative size, and complexity. The absolute size of urban features was calculated using QGIS software. LULC maps created through satellite data interpretation were applied to landscape analysis tools to evaluate the structural characteristics of various cover types. Each LULC class was considered, and every metric was computed and analyzed for every value.

6.2.1 Landscape Matrix Analysis/ Accuracy Assessments

Table 1 gives results using the patch matrix model in Landscape matrix analysis which helps understand land use systems and changes by interpreting quantitative landscape indicators. It quantifies metrics such as fragmentation, connectivity, and heterogeneity, providing insights into ecological integrity. In Makhado Biaba town within Makhado Local Municipality, it identifies areas needing interventions and explores social and economic implications of land use change, such as impacts on livelihoods and urban-rural dynamics.

Landscape Matrix SVM Classification_1995						
Class	Patch Density	Greatest Patch area	Mean Patch area	Number of Patches	Landscape proportions (%)	Land cover (HA)
Baresoil	$6.063432835820896\times10^{-3}$	1620.0	109.42307692307	26	66%	2845.0
build-up	$1.1194029850746268\times10^{-2}$	950.0	30.0625	48	34%	1443.0
TOTAL					100%	
Landscape Matrix SVM Classification_2011						
Class	Patch Density	Greatest Patch area	Mean Patch area	Number of Patches	Landscape proportions (%)	Land cover (HA)
Baresoil	$1.3489437515907355\times10^{-}2$	643.0	37.603773584905	53	24%	1993.0
build-up	$1.5525579027742428\times10^{-2}$	1013.0	31.737704918032	61	23%	1936.0
TOTAL					47%	
Landscape Matrix SVM Classification_2022						
Class	Patch Density	Greatest Patch area	Mean Patch area	Number of Patches	Landscape Proportions (%)	Land cover (HA)
Build-up	$1.0944260626113514\times10^{-2}$	1501.0	53.0	43	27%	2279.0
Baresoil	$3.0287604988546706\times10^{-2}$	745.0	13.865546218487	119	20%	1650.0
TOTAL					47%	

Table 1: Landscape Matrix Analysis for SVM Classifier (1995, 2011 and 2022). Source: Author, 2023

The study examines landscape structures using metrics such as Patch Density (PD), greatest patch area (GPA), mean patch area (MPA), number of patches (NP), landscape proportions (LP), and landcover area to study changes in LULC classes. The support vector classifier was used to calculate GPA values for buildup and baresoil. The results show landscape metrics play a crucial role in understanding landscape changes and their effects. In the year 1995, baresoil had the largest GPA at 1620, comprising 66% of the LP then the build-up with a GPD of 950 comprising 34% of the LP. In 2011, a shift occurred with build-up's GPA becoming the largest at 1013, occupying 23% of the LP, while the baresoil had a decrease in the GPA at 643, comprising 24% of the LP. By 2022, Build-up reclaimed the position with a considerable increase in the Greatest Patch area, reaching 1501 and constituting 27% of the LP. Population growth, economic activities, infrastructure development, and cultural influence, indeed indicate dynamic trends in the dominance and consolidation of Makhado Biaba town. while the baresoil had a GPA of 745.0, comprising 20% of LP.

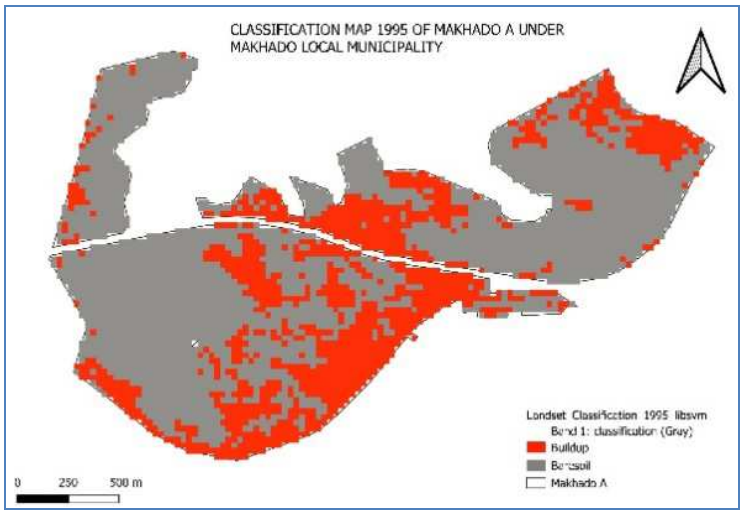

Figure 2: SVM classification results for 1995 in Makhado Biaba town. Source: Authors, 2023

6.3 Results and data interpretation of LULC classification and accuracies

The land use Land cover maps for the year 1995 (figure 1), the year 2011 (figure 2) and the year 2022 (figure 3), are based on supervised classification and visual interpretation, showing changes in Makhado Biaba town

over the years. Overall classification accuracy and landscape matrix, as well as the area of each land use and land cover, users' accuracy, and Producers accuracy.

6.3.1 Results for SVM in 1995, 2011 and 2022

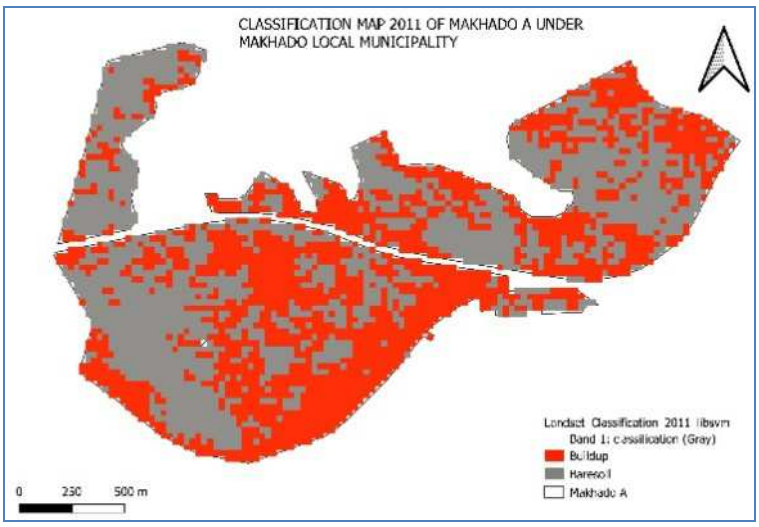

Figure 3: SVM classification results for 2011 in Makhado Biaba town. Source: Authors, 2023

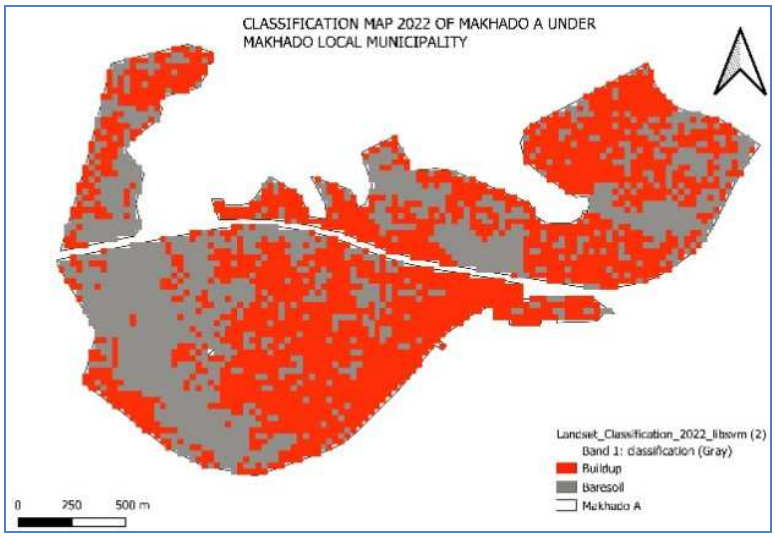

Figure 4: SVM classification results for 2022 in Makhado Biaba town. Source: Authors, 2023

The results from figure 1, figure 2 and figure 3 shows that there's a consistent decline in baresoil land cover from 2845 hectares in 1995 to 1650 hectares in 2022. The area decreased steadily, indicating potential factors of urbanization expansion. Build-up land cover shows an increase from 1443. Hectares in 1995 to 1936 hectares in 2011, followed by a slight further increase by 2279 hectares in 2022. This suggests urban development or infrastructure development and human settlement expansion over the years in the Makhado Biaba town. Leading to the reduction of baresoil areas, contributing to the conversion of natural land to build-up areas.

6.3.2 Accuracy assessment results for SVM (1995, 2011 and 2022)

Table 2 shows the validation test for land use and land cover (LULC) classification, the Support Vector Machine (SVM) algorithm for three different years: 1995, 2011, and 2022. The accuracy assessment for the training data in 1995 reveals a total accuracy of 82%, indicating a relatively high level of model performance, meaning the classifier has produced more true ground data and the maps are reliable.

6.4 Tests of association between socioeconomic statuses

The findings provided in Table 3, 4, 5, and 6 provide significant insights into the dynamics of peri-urban expansion in the small rural town of Biaba of Makhado local municipality. Firstly, the results highlight the

multifaceted drivers influencing settlement patterns, such as proximity to work, amenities, and family ties, as well as the availability of land and affordability. This indicates a complex interplay of socio-economic factors shaping individuals' decisions regarding where to settle. Secondly, the mode of land acquisition, predominantly through PTO (Permission to Occupy), highlights the informal nature of land tenure systems in these areas, suggesting a need for formalization and regulation to address issues of land ownership and rights. Thirdly, the demographic profile of residents, with a substantial portion being older adults and pensioners, suggests a potential trend of rural-to-urban migration among younger generations, which could impact the socio-economic landscape and service demands in these towns. Finally, the correlation between livelihood activities and educational qualifications highlights the importance of education in accessing employment opportunities, indicating potential areas for intervention to promote economic development and social mobility within these peri-urban communities.

Accuracy Assessment For SVM Classification Landsat (1995) for Training data 70%

		Reference Data			
		Baresoil	Build-up	Total	User' Accuracy
Classified Data	Baresoil	38	243	281	0,14
	Build-up	147	44	191	0,23
	Total	185	287	472	Kappa Index
	Producer's Accuracy	0,21	0,15	0,36	0,68
					Overall Accuracy 0,82

Accuracy Assessment For SVM Classification Landsat (2011) for Test data 70%

		Reference Data			
		Baresoil	Build-up	Total	User' Accuracy
Classified Data	Baresoil	27	154	181	0,15
	Build-up	226	34	260	0,13
	Total	253	188	441	Kappa Index
	Producer's Accuracy	0,11	0,18	0,287570431	0,69
					Overall Accuracy 0,80

Accuracy Assessment For SVM Classification Landsat (2022) for Test data 70%

		Reference Data			
		Build-up	Baresoil	Total	User' Accuracy
Classified Data	Build-up	69	0	69	1,00
	Baresoil	0	31	31	1,00
	Total	69	31	100	Kappa Index
	Producer's Accuracy	1,00	1,00	2	0,73
					Overall Accuracy 0,83

Table 2: Accuracy assessments, Confusion Matrix for the training samples results of SVM classification training data 70% (1995, 2011 and 2022). Source: Author, 2023

Place of residence * Pull factor for settling in the area									
			Pull factor for settling in the area						Total
			To be next to work	To be close to facilities	To be next to relatives	Bigger plots of land	Because it is cheaper to live in the area	Looking for land to reside in	
Place of residence	Makhado Biaba	Count	11	9	0	0	0	10	30
		% of total	6.1%	5.0%	0.0%	0.0%	0.0%	5.6%	16.7%
	Tshirolwe (ntha)	Count	2	3	12	6	5	2	30
		% of total	1.1%	1.7%	6.7%	3.3%	2.8%	1.1%	16.7%
	Tshituni (ntha)	Count	9	3	7	5	3	3	30
		% of total	5.0%	1.7%	3.9%	2.8%	1.7%	1.7%	16.7%
	Tshituni (fhasi)	Count	3	2	12	8	3	2	30
		% of total	1.7%	1.1%	6.7%	4.4%	1.7%	1.1%	16.7%
	Maphakhopele	Count	1	1	16	8	1	3	30
		% of total	0.6%	0.6%	8.9%	4.4%	0.6%	1.7%	16.7%
	Tshirolwe SP (Fhasi)	Count	4	1	13	3	1	8	30
		% of total	2.2%	0.6%	7.2%	1.7%	0.6%	4.4%	16.7%
Total		Count	30	19	60	30	13	28	180
		% of total	16.7%	10.6%	33.3%	16.7%	7.2%	15.6%	100%

Table 3: Place of residence, and pull factor for settling in the area. Source: Authors, 2023

Table 3 results indicate that out of the largest share equal to 33% (n = 60) of total participants who indicated the need to be next to relatives as a pull factor for settling in the area, the largest sub-share accounting for about 9% (n = 16) of total participants resided in Maphakhopele, followed by 7% (n = 13) who resided in Tshirolwe SP (Fhasi) and equal shares of about 7% (n = 12) who resided in Tshituni (fhasi) and Tshirolwe (ntha). From the second largest 17% (n = 30) who indicated the need to be next to work as the pull factor, the top two largest sub-proportions equal to 6% (n = 11) and 5% (n = 9) of total participants resided in Makhado Biaba and Tshituni (ntha), respectively. Furthermore, from the equivalent 17% (n = 30) of participants who indicated bigger plots of land as the key pull factor, approximately 4% (n = 8) resided in Tshituni (fhasi) and also 4% (n = 8) resided in Maphakhopele.

Place of residence * Process of acquiring land							
			Process of acquiring land				Total
			Inherited	PTO	Squatting	Deed of grant	
Place of residence	Makhado Biaba	Count	5	0	0	25	30
		% of total	2.8%	0.0%	0.0%	13.9%	16.7%
	Tshirolwe (ntha)	Count	6	24	0	0	30
		% of total	3.3%	13.3%	0.0%	0.0%	16.7%
	Tshituni (ntha)	Count	3	25	1	1	30
		% of total	1.7%	13.9%	0.6%	0.6%	16.7%
	Tshituni (fhasi)	Count	0	30	0	0	30
		% of total	0.0%	16.7%	0.0%	0.0%	16.7%
	Maphakhopele	Count	4	26	0	0	30
		% of total	2.2%	14.4%	0.0%	0.0%	16.7%
	Tshirolwe SP (Fhasi)	Count	4	26	0	0	30
		% of total	2.2%	14.4%	0.0%	0.0%	16.7%
Total		Count	22	131	1	26	180
		% of total	12.2%	72.8%	0.6%	14.4%	100.0%

Table 4: Place of residence and process of acquiring land. Source: Authors, 2023

Table 4 results reveal that out of the largest share equal to 73% (n = 131) of total participants who acquired land through PTO, the largest sub-share equal accounting for approximately 17% (n = 30) resided in Tshituni (fhasi), followed by equivalent shares of about 14% (n = 26) who resided in Tshirolwe SP (Fhasi) and Maphakhopele. From 14% (n = 26) of participants reported that they acquired land through the deed of grant, almost all of them resided in Makhado Biaba.

Main livelihood activity * Age group								
			Age group					Total
			18 - 25 years	26 - 30 years	31 - 35 years	36 - 40 years	> = 41 years	
Main livelihood activity	Employed	Count	1	3	8	17	15	44
		% of total	0.6%	1.7%	4.4%	9.4%	8.3%	24.4%
	Unemployed	Count	3	7	7	11	17	45
		% of total	1.7%	3.9%	3.9%	6.1%	9.4%	25.0%
	Self-employed	Count	1	1	9	7	9	27
		% of total	0.6%	0.6%	5.0%	3.9%	5.0%	15.0%
	Farmer	Count	0	0	2	0	2	4
		% of total	0.0%	0.0%	1.1%	0.0%	1.1%	2.2%
	Pensioner or grant	Count	1	1	3	7	48	60
		% of total	0.6%	0.6%	1.7%	3.9%	26.7%	33.3%
Total		Count	6	12	29	42	91	180
		% of Total	3.3%	6.7%	16.1%	23.3%	50.6%	100%

Table 5: Main livelihood activity and age group. Source: Authors, 2023

Table 5 results reveal that out of the largest share equal to 51% (n = 60) of total participants who were aged 41 years and above, the largest sub-share of about 27% (n = 48) were pensioners or obtaining a grant while 9% (n = 17) were unemployed and 8% (n = 15) were employed. The second largest share accounting for 23% of total participants was aged 36-40 years, out of which the largest sub-share equal to 9% (n = 17) were employed and 6% (n = 11) were unemployed. Out of the 16% (n = 29) aged 31-35 years, 5% (n = 9) were self-employed and 4% (n = 8) were employed.

Table 6 results show that from the largest share equal to 23% (n = 41) of total participants who had matric, the largest sub-share of about 11% (n = 19) were unemployed, and 5% (n = 9) were employed. From the second largest 22% (n = 39) who had a diploma, about 9% (n = 16) were employed, while equal shares of 6% (n = 10) were unemployed and self-employed. The third largest share of participants which accounted for about 16% (n = 29) of total respondents had no schooling, and out of these 16%, the largest sub-share equal to 14% were pensioners. From the 16% (n = 28) of those had a degree qualification, about 9% (n = 16) of them were employed.

Main livelihood activity * Highest educational qualification									
			Highest educational qualification						Total
			Degree	Diploma	Matric	Secondary level	Primary level	No schooling	
Main livelihood activity	Employed	Count	16	16	9	3	0	0	44
		% of total	8.9%	8.9%	5.0%	1.7%	0.0%	0.0%	24.4%
	Unemployed	Count	3	10	19	10	2	1	45
		% of total	1.7%	5.6%	10.6%	5.6%	1.1%	0.6%	25.0%
	Self-employed	Count	3	10	7	4	1	2	27
		% of total	1.7%	5.6%	3.9%	2.2%	0.6%	1.1%	15.0%
	Farmer	Count	2	2	0	0	0	0	4
		% of total	1.1%	1.1%	0.0%	0.0%	0.0%	0.0%	2.2%
	Pensioner or grant	Count	4	1	6	9	14	26	60
		% of total	2.2%	0.6%	3.3%	5.0%	7.8%	14.4%	33.3%
Total		Count	28	39	41	26	17	29	180
		% of total	15.6%	21.7%	22.8%	14.4%	9.4%	16.1%	100%

Table 6: Main livelihood activity and highest educational qualification. Source: Authors, 2023

6.5 Peri-urban dynamics challenges

To promote urban growth for future habitation, it is important to understand the process of land use change in the urban centre and along the rural-urban boundary. Land use and land cover are influenced by a variety of environmental, socioeconomic, political, and historical factors. In addition, these variables interact dynamically, resulting in a variety of landscape change sequences and trajectories depending on the particular situation they occur in. The participants were asked questions. The data was structured to demonstrate common viewpoints while also demonstrating the actual phrases used by the participants. The data collected from the participants was also confirmed by the literature review.

6.5.1 Land Governance in Makhado Local Municipality

What is often forgotten in the assessment of local government is that, before 1994, there were significant parts of the country where no local authorities existed. One of those areas is the rural areas of South Africa, where traditional leaders continue to be the face of local government. This is something which traditional leaders have been for many centuries. Traditional leaders serve as cultural custodians and cater to the needs of the communities they serve (Tshishonga and Sithole, 2022). Town planning officials in Makhado local municipality indicated that traditional leaders are expected to collaborate with municipalities to bring about development in the villages. However, due to the communal tenure system, it is frequently difficult for the municipality to facilitate development on tribal land. Since the municipality has limited authority over such areas, traditional leaders can allocate land that is unfit for human habitation. This makes it difficult for the municipality to control growth and align development with the goals of the municipality. The proposed intervention impacts the conflict to bring about the desired outcome. Theory of change states, that by engaging in the activities, one is hoping to achieve the goals, which will have a particular impact on the conflict and result in the desired change. Town planning officials continued to say that if the municipality had full control over tribal land, it might be in a better position to limit unstainable spatial development in the areas. There is also a division in decision-making between traditional leaders and municipal authorities. This has resulted in contradictory stand allocation whereby the traditional authority has placed some households in areas deemed unsuitable for development by the municipality. As a result, traditional authorities and municipal authorities must collaborate and have a good working relationship that is transparent and mutual.

6.5.2 Urban regulation and land use management.

Out of the sample of 5 traditional leaders who were interviewed about whether they were satisfied with the practice of land management in the study area, 3 (60%) of them were not satisfied with the land management practices in the area. These 3 traditional leaders gave various reasons as to why they were not satisfied as indicated in table 7.

Dissatisfaction with land management in the study area by Traditional Leaders
(1) The planning department uses a top-down approach
(2) Issues of land ownership between chiefs and local municipality
(3) Municipality wanting to take the roles and responsibilities of traditional leaders

Table 7: Traditional Leaders Views on Land Management. Source: Field Survey, 2022

The conflict between traditional leaders and local government structures continues to be a major issue in South African local governance. It is worth noting that more than 60% of the total sample of traditional leaders had reasons not to be satisfied with land management in their areas. All the reasons for their dissatisfaction pointed at the local government as the cause. As indicated in Table 7 traditional leaders argued that the local municipality uses a top-down approach which is the issue of inappropriate communication channels being used by the local municipality. One of the traditional leaders indicated that the reason why most traditional leaders show weak involvement in matters of land management with the local municipalities is not because of lack of willingness but rather a lack of understanding by local municipalities on the role and responsibilities of traditional leaders. This lack of appropriate communication affects poor working relations between local municipalities and traditional leaders. Although traditional leadership is often intended to address cultural and social issues, its importance in land use planning and management should be recognized. This argument stems from the fact that traditional leaders have accused local municipalities of manipulating them when they require community assistance, and they are rarely consulted.

Municipalities have been involved in numerous land disputes with traditional leaders, an indication that governance and administration are tipping. As indicated in table 7 the issue of land ownership between chiefs and the local municipality was brought up by one of the traditional leaders who provided an incident that happened between the Netshituni traditional leadership and the Makhado local municipality. In this incident, a dispute erupted over a plot of land measuring approximately 100 hectares in the area. The Netshituni traditional leadership contended that because the land belonged to them, the municipality had no legal right to auction it. The municipality, on the other hand, had already begun the auction process, and some people had already paid deposits for the auctioned land. However, the issue has been handed over to court and is being dealt with by the law.

6.5.3 Challenges of the land use scheme in terms of Spatial Planning and Land Use Management Act 16 of 2013 (SPLUMA)

Makhado town planning officials argued that the reality is that in rural areas there still exists a land use and land allocation system which is administered by traditional leaders in terms of customary law and this has been the case for many centuries. This has led to the emergence of two systems of land use management existing parallel to each other. The existence of the two systems in the same area potentially serves as a recipe for conflicts and contestations. Another serious issue which is proving to be challenging for Makhado local municipality is finalising their land use scheme. The town planning manager indicated that as the municipality is busy preparing the land use scheme, past legislations such as Proclamation 45 and R188 have not yet been repealed which will make it difficult for the municipality to effectively implement the wall-to-wall land scheme. The delay can also be attributed in part to the tensions between traditional leaders and the municipality. The town planners continued to indicate that municipal officials are often not allowed to assess and survey those areas where traditional leaders govern to include them in the municipality's land use scheme. Consequently, a significant amount of time and effort is lost trying to secure the buy-in and cooperation of traditional leaders to implement SPLUMA. The town planning manager indicated that Makhado Local Municipality is currently still in the process of finalizing their land use scheme which is in line with SPLUMA requirements.

7 SUMMARY AND CONCLUSION

The study provides a comprehensive understanding of the evolving landscape in Makhado Biaba town. Through the application of support vector machine (SVM) classification, the study tracks changes in land cover over three distinct time periods thus 1995, 2011, and 2022. Results highlight significant shifts in land cover composition, with notable implications for urban development, population growth, and socio-economic dynamics. Moreover, the research delves into the socio-economic factors influencing settlement patterns and land tenure systems. Traditional leaders play a pivotal role in land governance, complicating municipal efforts to manage and regulate land use effectively. Challenges such as conflicting roles between traditional leaders and local government structures, coupled with issues of land ownership and tenure, underscore the complexities inherent in peri-urban dynamics. These challenges are exacerbated by the coexistence of traditional land allocation systems alongside modern legal frameworks, leading to conflicts

and contestations over land use management. Furthermore, the study sheds light on the regulatory hurdles faced by the Makhado Local Municipality in implementing effective land use schemes, particularly in reconciling traditional and modern systems of land governance. Delays in finalizing land use schemes, tensions between municipal officials and traditional leaders, and legislative complexities hinder the municipality's ability to effectively manage land use in line with contemporary standards. Overall, the research underscores the need for collaborative approaches between traditional leaders, local government authorities, and relevant stakeholders to navigate the complexities of peri-urban dynamics and achieve sustainable land use management in evolving landscapes.

In conclusion, Monitoring and understanding the dynamics of LULC and peri urban expansion is essential for effective urban planning, environmental conservation, socio-economic development, and governance factors shaping land use and land cover change in peri-urban areas. By employing advanced classification techniques, landscape metrics analysis, and socio-economic assessments, the research contributes to a deeper understanding of the challenges and opportunities associated with urban expansion and peri-urban development.

8 RECOMMENDATIONS

The paper come up recommendations for sustainable urban development strategies in mitigating adverse effects on the environment and community well-being as listed and discussed below:

- Harmonize Legislation: Reconcile conflicting policies and By-laws to create a cohesive land management framework that accommodates both traditional practices and modern ordinances that is a comprehensive and integrated approach to land management by addressing conflicts between different legal frameworks.
- Facilitate multidisciplinary research to restructure the inherited spatial development pattern: This can be achieved by fostering partnerships between academic institutions, research organizations, government agencies, and non-profit organizations. Collaborative research projects can generate valuable insights into local dynamics, drivers of peri-urban expansion, and innovative approaches to sustainable land use and development.
- Compact Urban Design: Compact development encourages higher building densities, mixed land use, and efficient use of infrastructure, reducing the need for sprawling development and preserving green spaces.
- Capacity Building and Awareness: Implement programs to enhance the capacity of traditional leaders, municipal officials, and community members in understanding contemporary land governance frameworks, including land use planning, zoning regulations, and land tenure systems. Promote awareness campaigns to educate stakeholders about the importance of sustainable land use management and the benefits of adhering to legal and regulatory frameworks.
- Develop peri-urban expansion strategies: Strategies tailored to rural contexts, considering local needs, environmental impact, and community involvement.

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Circular Economy Principles and Planetary Boundaries

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1 ABSTRACT

Urban development requires a distinct understanding of the existing situations as well as a vision of the future district to be able to develop suitable pathways for a sustainable transition. The debate conducted so far highlights the need for a comprehensive understanding of the different aspects of circular economy (CE) principles impacting the sustainability, in particular what needs to be done with regard to environmental sustainability in cities and regions. To be able to build a representative methodology for integrated sustainability assessments the concept of Planetary Boundaries (PB) was selected as a framework to analyze how to establish a holistic sustainability evaluation based on CE. Previous work showed that although some principles have already been identified and implemented, several relevant trigger points of PB have not been considered yet. By combining CE methods, urban planners and policymakers can gain a holistic understanding of the impacts of urban districts on planetary boundaries. This knowledge can inform sustainable urban development strategies that minimize environmental harm, promote resource efficiency, and enhance the well-being of urban communities.

Keywords: economy, urban development., planning, sustainability, environment

2 INTRODUCTION

Various environmental problems such as biodiversity loss, water, air and soil pollution, resource depletion and excessive land use are increasingly threatening the Earth's life support systems. Especially in today's linear economic models with the "take, make, dispose of" concept raw materials are extracted, processed, used and then disposed of as waste (economiesuisse 2023). This approach leads to a high consumption of limited natural resources (Geissdoerfer et al. 2017).

Traditionally, the construction industry has also historically pursued an unsustainable, linear economic model based on the "take, make, dispose of" concept and seems to continue to do so (compare e.g. EMF, 2015). This linear approach does not allow for the targeted dismantling of buildings and the reuse of materials, components, or elements to conserve resources and reduce the need for new raw materials (Ghufran et al. 2022). The built environment plays a significant role in terms of resource consumption due to its significant environmental impact, but at the same time it also offers great opportunities to reduce energy consumption, greenhouse gas emissions and waste emissions (Pomponi and Moncaster, 2017).

A look at the annual status reports of the United Nations Organizations (UN), the International Energy Agency (IEA) and the Global Alliance for Buildings and Construction (GABC) shows the importance of the construction and real estate industry in the global context of energy consumption – the industries in question are responsible for 36% of global energy consumption and 39% of CO2 emissions (Röck et al., 2020). The figures from 2015 underline the importance of construction in energy and material consumption, also in Switzerland, where, for example, 40% of energy and 50% of material inputs were consumed, while at the same time 75% of waste was generated by this sector.

It is becoming clear that there is an urgent need for a transformation of the construction and real estate industry towards a circular approach. This is where the circular economy strives for better management of resources.

3 BACKGROUND

A recent study provided a practical application of CE in urban regeneration. It combined CE principles with urban redevelopment and showcased how traditional "brownfield" sites can be transformed into sustainable, vibrant communities. This approach represented an attempt to shift from the linear economic model, offering a replicable model for sustainable urban development driven by Nature-based solutions.

The integration of a CE models demonstrated that a conscious use of resources and a clear positioning against the linear economy is needed. The proposed method and tools not only offered efficient planning options, but also emphasised the emotional value of sustainability for the identity and history of the environment. Nevertheless, although the findings underline the effectiveness of this CERE model of energy generation and utilisation in the context of sustainability and the circular economy principles, it became clear that the implementation of a CE concepts often goes beyond technological progress by creating efficient, sustainable urban sites, there are certain shortcomings:

- The study contributed to the field by providing a practical application of CE in urban regeneration.
- It innovatively combined CE principles with urban redevelopment, showcasing how traditional "brownfield" sites can be transformed into sustainable, vibrant communities. It did not quantify the environmental benfits not the consequences in quantitative way.
- The approach represented a significant shift from the linear economic model, offering a replicable model for sustainable urban development driven by Nature-based solutions. However, it is not clear if these developments will help to stay within our planetary boundaries.
- In the realm of urban redevelopment there are approaches that redefine the transformation of traditional brownfield sites. Some extend beyond conventional approaches, exploring novel possibilities for real estate products. However, a clear link between urban development and planetary boundaries is still missing.

3.1 Circular Economy

Desing et al. (2020) highlight the lack of consensus and a uniform definition for "circular economy", despite its widespread use (also see Kirchherr et al., 2017). According to them, the Ellen Mac Arthur Foundation (EMF 2015) definition, which emphasizes the regenerative economy and new business models, is the most cited and recognized. This definition has been widely adopted or modified by policymakers and institutions like the European Commission.

The Laboratory for Applied Circular Economy (LACE) proposes a resource-based definition of the circular economy, aimed at human well-being, but acknowledging biophysical and planetary boundaries. These limits are considered absolute and quantifiable for the resource base used for human activities (LACE). Definition of the circular economy is:

The circular economy is a model that adopts a resource-based and systemic view and aims to take into account all the variables of the Earth system in order to maintain its viability for people.

In a recent study by Haase et al. (2024), a collection of CE models is presented that helps to complete our understanding of the opportunities and limitations of CEM. Important key strategies for the application of the circular economy over the entire life cycle of a building circular economy strategies in general were collected and its applicability for the built environment was reviewed.

One finding was that "The multitude of definitions of CE, and more specifically circularity in the built environment, does not contribute to a coherent, systematic approach. CE needs to be viewed as a business strategy, not only waste management or a design strategy. Optimising buildings' use should also be spotlighted instead of only viewing those as potential material banks where components and materials can be recovered, reused, or recycled for new constructions …. Still, recovered materials from existing buildings face a critical barrier in their technical compatibility and quality appraisal, which put their direct reuse in question, leading to downcycling processes and engaging extra resources and energy flows."

It further concluded that "The circular economy is seen as a regenerative system in which resource use and waste as well as emissions and energy losses are minimized, waste is avoided and material and energy cycles are slowed down, closed, and narrowed. This can generally be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, or recycling. In the context of the real estate and construction sector mentioned, this means that no new resources are required in the production of materials and waste is also minimized. In addition, better resource management is sought by reducing consumption (or even avoiding unnecessary consumption) and striving for resource circulation through the reuse or recovery of materials and components." (Haase et al. 2024)

The strategies could be assigned to the individual life cycle stages of a building, and differentiated between the design, construction, and end-of-life phases. Some key strategies are explicitly focusing on specific life cycle stages, such as Material Banks, Design for Adaptability, etc. On the other hand, most strategies include some sort of information and data management, like Adoption of Efficient Processes, Waste as a Resource, and Resources Data Management. By comparing the different origins, it explains the opportunities and limitations of the different models. Thus, it provided one important knowledge gap of our current understanding of CE. However, there seem to be more knowledge gaps that need to be filled.

3.2 Earth system boundaries

The concept of planetary boundaries describes limits to the impacts of human activities on the Earth system. These boundaries represent thresholds beyond which the environment may not be able to self-regulate anymore. It was proposed, in 2009, by Rockström and Steffen (Rockström et al. 2009; Stefffen et al. 2015). The concept introduced the much-discussed idea that, if we exceed these limits, we risk destabilizing the Earth system and moving away from the period of stability known as the Holocene, during which human society developed. The framework is based on scientific evidence that, since the Industrial Revolution, human actions have become the main driver of global environmental change.

In the PB concept, the thresholds, or tipping points represent the value at which a very small increase of the control variable (e.g., CO2) triggers a larger, possibly catastrophic change in the response variable (e.g., global warming) through feedback in the natural earth system. The threshold points are difficult to locate because the earth system is very complex. Instead of defining the threshold value, a range was established, where the threshold is supposed to lie inside it. The lower end of that range is defined as the boundary. Therefore, it defines a 'safe operating space', in the sense that as long as we (as mankind) are below the boundary, we are below the threshold value. If the boundary is crossed, we enter a danger zone (Steffen et al. 2015)

A recent study by Richardson et al., suggests (2023) that six of the nine boundaries are transgressed, which means that “the Earth is now well outside of the safe operating space for humanity” (Richardson et al. 2023).

The focus in future research is on quantifying the control variable PB of ‘green water’ and understanding the risks and dynamics through which ‘green water’ perturbations can disrupt Earth system resilience.

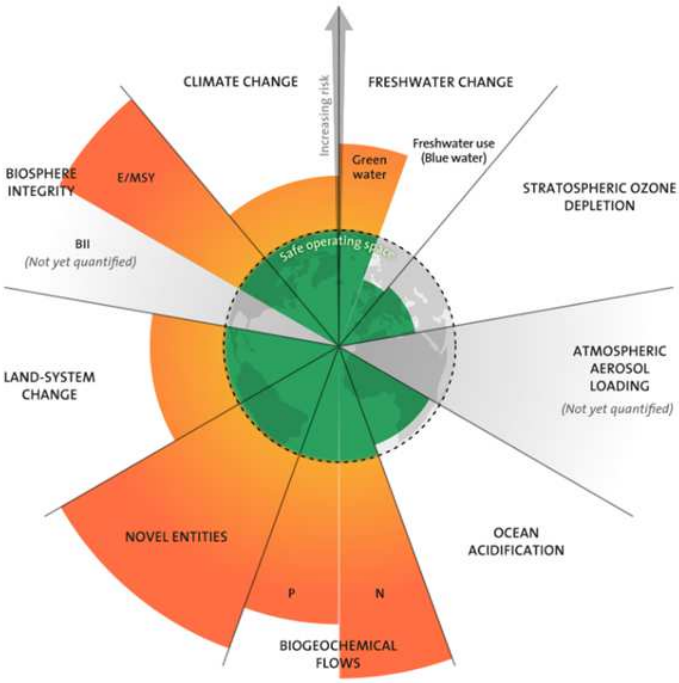

Figure 1: Estimation of planetary boundaries change from 1950 to 2022 (Wang et al. 2022)

It should aslo be noted that on the other hand there are some PB not yet quantified. So some efforts are put on defining those PB. E.g. Novel entities refer to substances, materials, and organisms that are introduced into the environment as a result of human activities. These can include i) chemicals and plastics; ii) new materials ii) genetically modified organisms (GMOs). The concept of a planetary boundary for novel entities

is still under development, however, some scientists believe it has already been transgressed due to the widespread presence of plastics and chemicals in the environment. Wang et al. (2022) collected or more details on each PB shown in Figure 1.

4 METHOD

The approach involves:

- Dicussion of CE principles for the Real Estate and urban development
- Collection of tools and methods that are needed
- Analysis of value creation and its relation to planetary boundaries

5 INTRODUCTION OF THE CERE MODEL

Based on the case study a method was developed and is presented that is based on four pillars:

(1) Determination of CE concept and alocation in the Circular Economy in Real Estate (CERE) model

(2) Choice of a method and a tool for the chosen CERE model

(3) Determination of data needed to measure the circularity, including stakeholders identification

(4) Specification of business model by using Sustainable Business Model Innovation (SBMI) to specify all input needed.

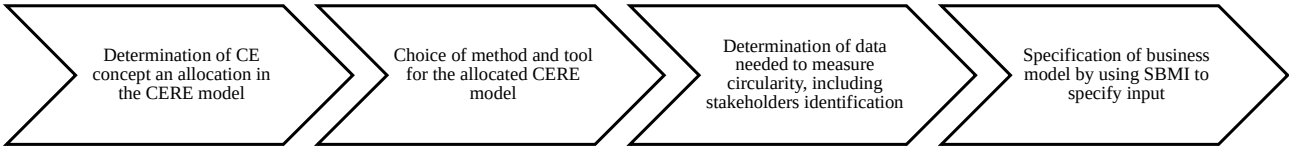

Fig. 2: CERE model for urban sites

5.1 CE concepts

Based on an analysis of existing CE models, a new model tailored to the real estate lifecycle management was proposed (Haase et al. 2024) Here, the principle should be allocated as described in Table 2.

CE Principle	Description and planetary boundary impact
Ressource Efficiency	Reducing the demand for raw materials impacts the Earths biochemical flows. Reducing energy consumption impacts the climate change. Minimising land and resource use impacts the change in the land-system
Regeneration	Implementing regenerative practices, such as green roofs or parks influences the biodiversity loss boundary by creating habitats and supporting ecosystem services.
Reduce	Restricting resource flows throughout the life cycle of buildings (Share, Reuse, Repair) affects several boundaries, including climate change (reduced greenhouse gas emissions), freshwater use (lower consumption), and land-system change (less resource extraction).
Decelerate / Slow	Slowing down resource flows by intensifying use and extending useful life influences the planetary boundaries related to waste production and resource depletion.
Closing	Returning resources to the cycle at the end of their life affects mainly the chemical pollution boundary.
Cooperation	Fostering collaboration between supply chain actors facilitates a holistic management of all boundaries by promoting integrated solutions.
Digitalization	Efficient handling and systematic collection of information and data over the entire life cycle of a building to increase transparency, traceability and optimization of processes would impact all boundaries.

Table 2: Basis of CE principles in CERE model (Haase et al. 2024) and their impact on planetary boundaries

By incorporating these principles, the real estate sector can play a crucial role in maintaining the Earth's systems within safe operating spaces, addressing multiple planetary boundaries, and contributing to a sustainable future.

5.2 Methods and tools measuring circularity and the contribution to Panetary Boundaries

In practice, the circular economy encompasses a broad range of industries, from manufacturing and construction to fashion and electronics. It involves adopting innovative technologies, material recycling, reverse logistics, and sustainable procurement practices to close the loop on product lifecycles. This step involves choosing a method and a tool from real estate lifecycle which you would apply for your case. This step should be supported by giving the reasons for the choice and specification of the information need to use the tool amd method. There are emerging tools and methods that can be explored. They differ in how to quantity the circularity of a proposed measure.

Beyond waste reduction, the circular economy seeks to regenerate natural systems. This includes promoting regenerative agriculture, reforestation, and sustainable land use practices to restore ecosystems and biodiversity. The urban developer should explain how he/she would measure the circularity of his/her project. It starts with listing the data needed to measure the circularity, which stakeholders are needed to involve, and which values are created in the project.

Ultimately, the tool should relate to the planetary boundaries. What trigger points are moved in which direction and by how much? Is it beneficial to do the urban development or does it increase the trigger points?

Table 3 shows emerging tools that are currently under development. They focus on different levels (Building, Component, Material) and in different phases. An important distinction is the post-use phase and the pre-use phase. While pre-use phase focuses on the period before the start of the use phase. Finally, a dinstinction can be made regarding the sub-indicators.

method / scope		Circularity score (SC)	Concular Circularity Performance Index (CPX)	DGNB Circularity Indesx (DGNB CI)	EPEA Circularity Passport Buildings (CP)	IBO Disposal Indicator (EI)	Madaster Circularity Indicator (MCI)	Urban Mining Index (UMI)	Recycling Graph	Circularity Index BSRRI
level		B C M	B C M	B C M	B C M	M	B M	B C M	C M	B C M
phase		post-use	pre-use, post-use	pre-use, post-use	pre-use, post-use	post-use	pre-use, post-use	pre-use, post-use	post-use	post-use
sub-indicator	pre-use		material origin construction waste, pollution	material origin, construction waste, pollution	material origin, CO2 pollution		material origin, CO2 pollution	material origin, CO2 pollution, pollution		
	post-use	R DA MR	R DA SRM MR	MC R DA SRM MR	 DA SRM MR	 MR	 DA MR	MC R DA SRM MR	 DA MR	MC R MR

Table 3: Emerging tools for circularity. B: Building level; C: Component level; M: Material level, MC: Material compatibility; R: Reusability, DA: dismantling ability, MR: material recycling; SRM: separability of recyclable materials

Circularity score (SC)

This method was developed at RWTH Aachen in Germany with the goal to establish a widely applicable and easy-to-determine indicator of the expected circularity of buildings. So far, only a few approaches exist in the academic environment of a few colleges and universities. A higher level of applicability of the Circularity Score is envisioned in an early planning phase, e.g. the HOAI - Phase 2 (pre-planning). This ex-

ante approach makes it necessary to examine and evaluate numerous fundamentally possible and probable combinations of building materials in a building with a view to their later separation and reusability. The BBSR's eco-building data, which is frequently used in the construction industry for life cycle assessment issues, knows over 1,000 building materials and components from which possible and probable building material combinations are determined. These are then aggregated in the context of the building to form a total number named the Circularity Score.

Concular Circularity Performance Index (CPX)

The Concular Circularity Performance Index (CPX) is a tool developed by Concular specifically for assessing the circularity of buildings and construction projects. CPX is specifically tailored to the construction sector, considering aspects relevant to building materials, design, and end-of-life options.

Quantitative Assessment: It assigns a score (likely ranging from 0 to 100) to a building project, providing a quantifiable measure of its circularity performance. It leverages Concular's own database of materials, pre-populated with circularity factors for various building components. This can streamline the assessment process. The initial score can be adjusted by planners or building owners to reflect project-specific details and decisions. Public information about the specific methodology behind the CPX is scarce. Transparency regarding how the score is calculated is crucial for users to understand its strengths and limitations. Thus, the accuracy of the CPX assessment relies heavily on the comprehensiveness and quality of data in Concular's internal database. Since Concular offers other circularity-related services, there might be a concern about potential bias towards their solutions when using the CPX.

DGNB Circularity Indesx (DGNB CI)

The Circularity Index of DGNB (DGNB CI) is a tool developed by the German Sustainable Building Council (DGNB) to assess the circularity performance of buildings. DGNB is a well-recognized organization in sustainable building practices, lending credibility to the DGNB CI. The index considers the building's entire life cycle, from material extraction and construction to use and end-of-life management. This aligns well with circular economy principles. DGNB CI goes beyond just material circularity. It incorporates aspects like design for disassembly, potential for reuse and recyclability, and waste management practices during construction and demolition. The methodology behind the DGNB CI is publicly available, allowing users to understand how the score is calculated and interpret the results effectively. The DGNB CI can be complex to use, especially for projects without prior experience with DGNB's sustainability rating system. Conducting a comprehensive assessment using DGNB CI requires detailed information about building materials, their origins, and potential for reuse or recycling. Gathering this data can be time-consuming and resource intensive. While the core principles of DGNB CI are applicable globally, some aspects might have a regional focus, potentially requiring adjustments for application in different geographical contexts.

EPEA Circularity Passport Buildings (CP)

The EPEA Circularity Passport Buildings (CP) is a tool developed by EPEA, a consultancy specializing in cradle-to-cradle design principles. It focuses on creating a digital record of a building's materials and their circularity potential. The EPEA CP promotes transparency by creating a digital passport that tracks the materials used in a building. This facilitates future reuse, recycling, and overall material management. EPEA's cradle-to-cradle approach emphasizes using healthy and environmentally safe materials in construction. The CP reflects this focus, potentially leading to buildings with a positive impact on human and environmental health. The EPEA CP can be integrated with design and construction workflows, promoting circular considerations from the outset of a project. The digital passport concept could be used in future applications like facilitating material exchanges or connecting buildings with dismantling and recycling facilities. The EPEA CP primarily focuses on material documentation. It doesn't provide a comprehensive circularity score or assessment of other aspects like design for disassembly or operational efficiency. The accuracy of the information in the CP relies on the quality of data entered by designers and builders. Integrating the CP effectively within existing design and construction workflows might require additional training or adjustments for project teams.

IBO Disposal Indicator (EI)

The disposal indicator was prepared by the Austrian Institute for Healthy and Ecological Building (IBO) for the uniform assessment of the disposal properties of construction and materials at building level. In the semi-

quantitative method, the current disposal route of a component or the recycling potential that would be possible from an economic and technical point of view if the framework conditions were improved up to the assumed point in time of disposal of the construction product are evaluated on a scale of 1 to 5. The higher the expenditure for dismantling and recycling and the more negative the effects of disposal are on the environment, the worse the classification at building material level. The disposal indicator plays an important role in the climate-active building evaluation programmes Building and Renovation and Total Quality Building (TQB).

Madaster Circularity Indicator (MCI)

The Madaster Circularity Indicator (MCI) is a tool developed by Madaster, a platform focused on building transparency through material passports. It assesses the circularity performance of buildings throughout their life cycle. Madaster's MCI is directly linked to their material passport system. This creates a seamless connection between documented building materials and their circularity potential. The MCI considers all stages of a building's life cycle, from material extraction and construction to use and end-of-life management. Madaster emphasizes transparency by allowing building owners and stakeholders to access detailed information about the materials used in the building. The accuracy of the MCI score heavily relies on the completeness and quality of data recorded within the Madaster platform's material passports. The specific methodology behind the MCI calculation might not be entirely transparent to users outside of the Madaster platform. Madaster offers various circularity-related services. There might be a concern about potential bias towards their solutions when using the MCI.

Urban Mining Index (UMI)

The Urban Mining Index (UMI) is a tool developed to assess the potential for recovering and reusing materials from buildings at the end of their lifespan. It focuses on the concept of "urban mining," which refers to extracting valuable resources from existing structures rather than relying on virgin materials. The UMI specifically targets the potential for recovering and reusing building materials, aligning well with circular economy principles. While the primary focus is on the end-of-life stage, the UMI might consider aspects throughout a building's life cycle that could influence its disassembly and material recovery potential.

Quantitative Assessment: The UMI aims to provide a quantifiable score or indicator to assess the recoverability of a building's materials. Information about the UMI can be scarce. The specific methodology behind the UMI calculation and details on how the score is interpreted might not be readily available. Using the UMI effectively might require expertise in building materials, deconstruction practices, and market conditions for recycled materials. The UMI's development might have originated in a specific context. Its applicability in different regions could be affected by factors like local regulations and recycling infrastructure.

Recycling Graph

The RecyclingGraph approach was developed by Schwede (2019) can be used to translate detailed models of constructive designs into a numerical representation that can be processed by computational algorithms and design tools (SChwede 2019). This method can be utilized to evaluate designed and pre-designed structures and a catalogue of qualified design templates can be build up to support the BIM-based design development. The RecyclingGraph approach has potential to be further developed and implemented in applicable design tools. However, further aspects could also be integrated, e.g. on the ability of disassembly for common connection principles or on the compatibility of material combinations.

5.3 Value creation and planetary boundaries

The circular economy is gaining global momentum, as various organizations, governments, and businesses actively pursuing circularity to tackle urgent environmental challenges, lower carbon emissions, and foster economic resilience in an increasingly resource-constrained world. The final step involves specifying the project`s business model. To achieve this, the SBMI framework can be utilized, requiring specific inputs. These include defining the value creation process, identifying stakeholders and their roles in the project, and outlining the market opportunities for the business concept.

At the core of effective circular business innovation is design thinking, a methodology that emphasizes human needs, empathy, and collaboration (Lawson 1997).

Once a sustainable business innovation has been identified and a CE concept has emerged, it is crutial to include evaluation of the trigger points of our planetary boundaries.

- Global freshwater systems considerations should be centrally embedded in the local water cycle in urban planning and design processes, deploying Nature-based Solutions, and resource circularity. Aiming at sustainable water management, rainwater collection, treatment, and reuse, as well as selecting building materials and products with low water inputs can further reduce impacts on freshwater resources. The goal must be to improve the availability of water sources while minimizing ecological impacts and reducing flood risk. A proactive management of natural water processes through Nature-based Solutions, from catchments to buildings and open spaces.
- Urban developmnets influence biodiversity and degradation of the quantity and quality of urban habitats. So, the focus should be on reducing the embodied ecological impacts in materials, food, and other products; and planning linear infrastructure to protect, restore, and connect habitats. A prioritization of resilient vegetation in urban green spaces can improve species intactness and biodiversity through appropriate habitat provision. Another focus should be put on the blue-green infrastructure which helps to improve aquatic biodiversity. This implies improved water quality through reduction and appropriate management of contaminated runoff; the enhancement of treated sewage discharge; the support of conscious water use; and the restoration of freshwater and coastal habitats.
- Urban infrastructure is a critical component in redirecting nutrient flows to balance areas of excess to areas of need and to close cycles. Sewage sludge, food, and yard waste can become resources rather than costs if appropriately managed in a circular metabolism approach. These nutrient inputs can be converted into biogas through anaerobic digestion, which produces a by-product called digestate. Digestate from food and yard waste can then be applied as a fertilizer and/or soil amendment to improving soil qualities and reducing the need for chemical fertilizer. In urban developments, opportunities to create local facilities to enable circular nutrient flows can be identified. Strategically placed green-blue infrastructure and Nature-based Solutions, such as raingardens, bioswales and wetlands, can reduce eutrophication by safely soaking up nutrients in runoff. Planned in a “good” way, urban sites can also reduce indirect nutrient pollution from agricultural imports through sustainable food sourcing and by scaling up local food production. Hydroponics and other sustainable production systems, when contained in controlled environments, tend to have high nutrient efficiency and little to no runoff.
- There is a possibility in urban developments to reduce aerosol pollution by mitigating the major sources of particulate emissions, including use of fossil fuel combustion for energy, transport, and industry, and minimizing construction and demolition dust. Clean or electrified heating and cooling, transport, cooking, and industry from renewable sources can reduce local emissions. Electricity generation must also be emissions free to avoid simply shifting the geography of aerosol loading.
- Clean and renewable energy generation (in addition to demand reduction) is fundamental to reducing net loading, yet intermediate actions can be taken during the infrastructure transformation to immediately reduce aerosol emissions such as retrofitting existing power plants with wet scrubbers that remove particulates at the source. In sectors that are challenging to electrify, hydrogen fuel can be used; the only aerosol emitted through its combustion is water, yet the hydrogen must be produced cleanly as well.
- Dust emissions can be reduced during construction and demolition through controlled deconstruction (which supports component reuse), the use of protective screening, and the application of water for damping down.
- Vegetating temporarily vacant lots can reduce dust emissions and mitigate the urban heat island effect while supporting local biodiversity.
- Novel entities cause a major concern, with widespread plastic pollution and the introduction of various synthetic chemicals into ecosystems. Also engineered nanomaterials and other advanced materials raise concerns about their potential long-term environmental impacts. The introduction of genetically modified organisms into the environment poses potential risks to biodiversity. The long-

term effects of novel entities on ecosystems and human health are often not fully understood. Design of urban areas under CE principles should therefore avoid these novel entities despite their unpredictability.

6 DISCUSSION

From this research it becomes clear that there is an urgent need to link CE principles with planetary boundaries. Only if we manage to quantify the amount of moving trigger points with the help of CE principles it will allow us to quantify the real value of CE.

Planetray boundaries have the potential to add useful inventory of the current use of the circular economy concept in the built environment. It has not been incorporated yet because there are several issues

(1) The planetary boundaries have been found for our activities on the planet. It is yet to be downscaled to national, regional or even local dimensions. Attempts for this have been made (add ref.) but it remains unclear how effective this approach is.

(2) To upscale local activities towards PB is anotother promising approach (add ref.). However, this implies asessment and certification schemes that are already on the market (and have customers in the building industry) adopt these boundaries. The definitions and effects on the cicular economy are not yet established and there can be expected some resistance from major actors against the consequences from establishing PB in the construction industry.

(3) To date, there is no consensus on the planetary boundaries, how they are measured and assessed, and this issue would also need to be addressed (e.g. agreed targets of GHG emissions and lack of implementation) with focus on the building industry.

It will be important to explore further the relation between measures on the existing building stock and the materials, components, and buildings already in use and new constructions and their impact on the future life period of the urban site. In this sense, each urban development has two aspects to measure the circularity, a pre-use and post-use circularity. More work is needed to develop these methods further.

7 CONCLUSION

The study of the methods and tools currently under development shows that their focus is not on the planetary boundaries. Some tool was developed mainly with the aim to minimize impact compared with a “base case”. Then certain measures can be used to offset impacts (e.g., the renewable electricity produced onsite can be used to offset GHG emissions from the grid). This concept is therefore heading only for a better than usual approach and does not appear congruent with the planetary boundaries approach, which is framing precise thresholds for development. On the other hand, the CE does not try to stay within the planetary boundaries. On the contrary, a CE use is allowed for every citizen, and even though this implies a very small footprint, it allows certain boundaries to be reached and crossed.

There are two key aspects that need to be integrated: First, starting with PB, there should be a regionlising of tipping points in regenerative sustainability models for the built environment. This would allow us to plan and design for urban and peri-urban ecosystems that stay within the planetary boundaries.

Secondly, regeneration of the full Earth system will require a fundamental shift in the way we think about our relationship with the planet. We have to re-think what a balanced human-planet relationship might look like and ultimately provoke passion to drive change for ourselves and the next generation. Urban developments can have a profound impact on the PB. By adopting sustainable and environmentally responsible urban development practices can help to protect the planet, enhance resilience to climate change, and create healthier, more equitable communities for future generations.

By combining CE methods, urban planners and policymakers can gain a holistic understanding of the impacts of urban districts on planetary boundaries. This knowledge needs to be developed further as it can inform sustainable urban development strategies that respect the Earth`s limits, while promoting economic growth, resilience, resource efficiency, and enhance the well-being of urban communities.

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🏆 *reviewed paper*

Climate Change Impacts on Food (In)Security: a Case Study of Enyezane, Kwazulu-Natal, South Africa

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1 ABSTRACT

Climate change significantly threatens food security, and localized studies are crucial for effective responses. This study examines the impacts of climate change on food security in Enyezane, KwaZulu-Natal, South Africa. Enyezane faces increased climate-related shocks like droughts and temperature extremes, leading to crop failures, reduced agricultural yields, and water scarcity. The study explores these challenges and the community's coping mechanisms, including diversifying crops, using resilient varieties, and relying on traditional knowledge and social networks. The importance of urban planning in mitigating food insecurity is highlighted. Planning can promote climate-resilient agriculture, efficient water management, and community-based food systems. This study calls for government support, social safety nets, and infrastructure development to bolster food security in Enyezane, aligning with the Sustainable Development Goals. The study emphasizes the adverse effects of climate change on Enyezane's food security. It analyzes the community's coping strategies while highlighting the potential of urban planning to address these challenges. The findings offer valuable insights to inform policies and targeted interventions that can promote food security and climate resilience in Enyezane, and similar regions facing the impacts of climate change.

Keywords: Climate change, food security, Enyezane, South Africa, Climate resilience

2 INTRODUCTION AND CONTEXTUALIZATION

Most developing countries have enormous issues in terms of food security as a result of climate change. Food insecurity affected approximately 30 million more individuals in low-income countries in 2021 as a result of increased food commodity prices, which was a significant contributing factor (World Bank, 2022). In all regions of the world, there is widespread food insecurity and malnutrition in all its forms (FAO, 2022). Achieving goal 1, which is no poverty, and goal 2, which is end hunger, of the Sustainable Development Goals (SDGs) has been challenging in recent times, as indicated by the 2022 Global Hunger Index (GHI) study. This study also suggests that the recent global progress in addressing hunger has come to a halt (Von Grebmer et al., 2022). If hunger-eradication efforts are not stepped up, 8% of the world's population would be hungry by 2030 (Food and Agriculture Organization et al., 2022). The severity of the issue is most extreme in Asia, where 10.2% of the population experienced acute food insecurity in 2020, up from 319.9 million in 2015 (UNICEF, 2021). More than half (425 million) of the hungry people in the globe in 2021 resided in Asia (FAO, 2021). Furthermore, except for Asia, moderate to severe food insecurity has remained consistent. According to UNICEF (2021), food insecurity distribution varies substantially even within the Asian region. For example, the proportion of malnourished persons in 2020 ranged from 2.5% in Eastern Asia to nearly 15.8% in Southern Asia (UNICEF, 2021). In contrast, the rate of undernourishment in Western Asia (15.1%) was nearly comparable to that in Southern Asia (UNICEF, 2021).

Hasanuzzaman et al., (2013), stated that higher temperatures hamper crop development and raise the danger of pests and diseases, which lower crop yields (Hasanuzzaman et al., 2013). It also affects precipitation patterns, which results in short-term crop failure and a long-term loss in food output (Pörtner et al., 2022). Additional studies have shown that water scarcity, usually associated with drought, reduces soil moisture and causes low yields (Mar et al., 2018). Nonetheless, heavy rain that washes away topsoil affects soil fertility through deterioration and hence reduces crop yields (Shourie and Singh, 2021). Early rains before a planting season disrupt planting and harvesting seasons, causing food insecurity (Kyei-Mensah et al., 2019).

Climate change has raised serious concerns about future water availability in many parts of the world, as it impacts factors such as precipitation, which has ramifications for hydrological systems, water quality, and groundwater recharge (Masipa, 2017). These all pose significant obstacles to climate adaptation. In general, climate change depletes water supplies and has an impact on vulnerable communities' health and food

security, especially in southern hemisphere nations with limited capacity to adapt (Malhi et al., 2021). According to Ogundeji (2022), the African continent is especially vulnerable to climate change because of the greater-than-average temperature increase that will result from global warming, and because agriculture, primarily rain-fed, serves as the main means of subsistence for rural communities. Furthermore, rural homeowners and farmers are particularly vulnerable to climate change due to additional issues such as a lack of access to land, acute poverty, and lack of knowledge and financial support to implement adaptation measures (Ogundeji, 2022). Climate change has jeopardized the food security of millions of people in Sub-Saharan Africa. Climate change will exacerbate drought conditions in Sub-Saharan Africa and across the continent, making water security for food and agricultural development more challenging (Simpson, 2016).

South Africa is a country with significant food insecurity challenges. According to the Global Hunger Index (2020), South Africa has a hunger index score of 13.5, indicating a serious level of hunger. The country's food insecurity is mainly due to factors such as poverty, unemployment, and inequality. The country's population growth rate is currently at 1.28%, which is higher than the global average of 1.05%. Food security is a critical issue in South Africa, where the population is growing at a rapid rate. The country's population growth is projected to increase from 58 million in 2020 to 79 million by 2050, according to the United Nations. This growth is expected to place significant pressure on the country's food production and distribution systems (Index, 2020).

With reference to the above context, this study focuses on the Enyezane area located in KwaZulu-Natal, South Africa. Climate change poses immense challenges for food security in most areas of South Africa. Jacob Zuma, a former president of the Republic of South Africa, said in his 2014 State of the Nation Address that the government has elevated food security to a major priority (Masipa, 2017). This is because South Africa and other countries across the world are increasingly acknowledging that climate change and its effects on food insecurity are serious issues. South Africa is usually regarded as a food-secure nation when compared to other African nations since it produces enough staple foods and can import food to meet the population's basic nutritional needs (FAO, 2008). Hart and Aliber (2009) make a similar argument, arguing that while South Africa may appear to have enough food security on the national level, this cannot be stated for individual households, particularly those located in rural areas where agriculture is the primary source of income for the vast majority of residents. However, Landman (2004) discovered that South Africa continues to have a significant problem concerning food security.

In terms of the Constitution of South Africa specifically Section 27 (1)(b) everyone has a right to sufficient food and water. This is also consistent with South Africa's millennium development goals, which call for cutting poverty in half by 2015. Even though South Africa has been able to fulfill the food needs of its expanding population over the years, according to national food security indicators, there are no reliable data on food security at the household level (Statistics South Africa, 2009). According to Hendriks (2005), in South Africa, a high number of rural households are affected by food insecurity. According to research by Knueppel et al. (2009) and De Cock (2012), South Africans who live in rural areas are the most severely impacted by climate change which led to food insecurity. More than 14 million individuals, or roughly 35% of South Africa's population, are subject to food insecurity (Demetre, Yul, and Zandile, 2009). The authors claim that if a person receives less than R211 per month, they are considered to be food insecure. The main issue with food security in South Africa, according to Bonti-Ankomah (2001), is the availability of food. This is so because the availability of food is influenced by demand and disposable income.

People in KwaZulu-Natal are now more vulnerable to future climate change as a result of the multiple daily pressures in their life. Additionally, efforts to reduce the hazards associated with climate change are constrained by a lack of organizational support (e.g., from the government and other organizations) (Ndlovu et al., 2021). The province has a largely rural population, and the majority of people their live-in high-density poverty. KwaZulu-Natal is characterized by warm to scorching summers, heatwaves, wildfires, and moderate winters. In the area surrounding Cape St. Lucia, the highest daily air temperatures during the summertime can reach 40.1 °C (Ndlovu et al., 2021). The province has experienced a falling water presence throughout time, and it is expected that things will become worse before they get better (Shen et al., 2017). In a study on adjusting to climate change in KwaZulu-Natal, it was shown that women in rural regions have been suffering from reduced harvests owing to drought, with the diversification of livelihoods through fishing having been hampered as water sources have dried up (Yende, 2020). According to Yende (2020), due to their scarce financial, human, and technological resources, lack of support from the municipal and provincial

governments, and other factors, rural households are more severely impacted by the negative effects of climate change. Unfortunately, for those who have cattle, a short-term drought approach has been switching from cropland to livestock, but this reduces natural capital (Bahta and Myeki, 2020). Food security in KwaZulu-Natal has been and will continue to be significantly impacted by climate change, like many other provinces in South Africa.

Given the above, the study addresses the following question; how have climate-related shocks impacted food security in Enyezane, and what coping strategies has the community employed to overcome these challenges?

3 BACKGROUND ON STUDY AREA

Enyezane is a rural area in Estcourt, KwaZulu-Natal Province, South Africa, in the uThukela District.

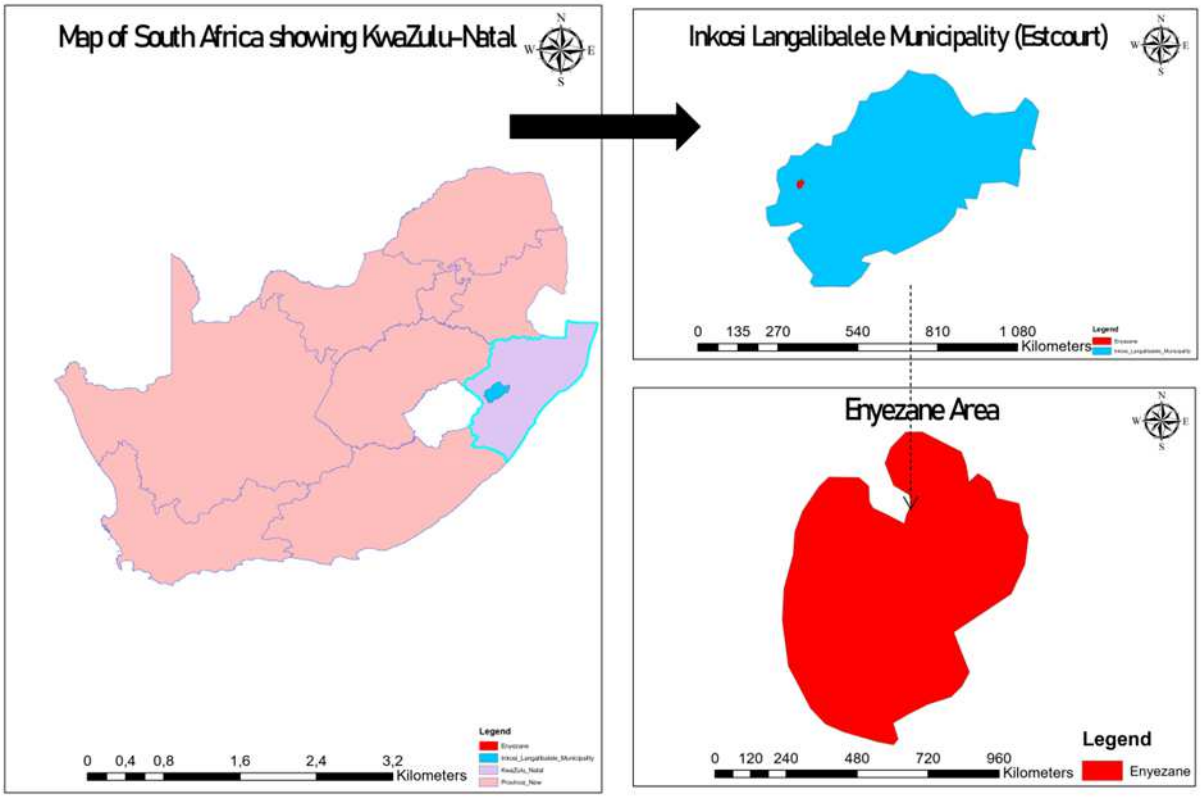

Fig:1 Locality map of Enyezane: KZN, Inkosi Langalibalele Municipality, and Enyezane

Farming is the main economic activity in Enyezane, and there are sizable bacon and processed food plants positioned all around the town. The area is connected to the rest of South Africa by the N3 highway, which runs close by. Enyezane which is under Estcourt is located at the confluence of the Bushmans and the Little Bushmans River. It is also on the main Durban and Johannesburg railway line some 160 km north of Durban and 25 km south of the Tugela River crossing (Inkosi Langalibalele Disaster Management Draft Sector Plan 2017/2018, 2017). Enyezane is under Inkosi Langalibalele Local Municipality. The population of the Municipality as a whole is 223 898 people (Final integrated development plan review 2020/2021, 2020). The majority of the population is African, which makes up 91% of the total population. Like many other municipalities, this particular one exhibits a higher female population, with women comprising 54% of the municipal residents, while men make up the remaining 46%. Furthermore, in this municipality, women lead 52% of households (Final integrated development plan review 2020/2021, 2020). Given that farming settlements make up the majority of the municipal area, male absenteeism is a sign that most farmers are no longer engaged in traditional commercial agricultural activities, which typically use men as labor, and as a result, the majority of men look for employment in major urban centers elsewhere in the world (Final integrated development plan review 2020/2021, 2020). The figure below shows the spatial context of Enyezane.

4 LITERATURE REVIEW: FOOD SECURITY AND CLIMATE CHANGE

The Intergovernmental Panel on Climate Change's (IPCC) Working Group I Sixth Assessment Report (released on 6 August 2021) outline that the world average surface temperatures could increase by 1.0°C to 5.7°C by the end of this century. The rate of global mean sea level rise has accelerated and will continue throughout the 21st century, ranging from 0.32m to 1.01m. 2021 was Singapore's second wettest year since 1980, with higher-than-average rainfall for most months and annual total rainfall of 2809.6mm at the Changi climate station. (From "2021 Climate and Weather: The Year in Review", NEA). While a localized temperature change of 2°C or 3°C may not seem serious, it has grave consequences on a global scale because this temperature increase directly impacts the sustainability of water, food supplies, ecosystems, coastal stability, and public health (Tol, 2018). In the context of this study, climate change can be defined as the long-term alteration of temperature, precipitation patterns, and other climate variables in the Enyezane region of KwaZulu-Natal, South Africa. This phenomenon is primarily driven by human activities, such as the emission of greenhouse gases from industrial processes, transportation, and deforestation. Climate change in this context encompasses both gradual shifts in average weather conditions and an increase in the frequency and intensity of extreme weather events, including droughts, heatwaves, and heavy rainfall.

Climate change is expected to disrupt food production in various regions worldwide, causing increased food prices and significant adverse effects from 2050 to 2100 (Dawson et al., 2016). The United States, with its high carbon dioxide emissions, experiences record-breaking temperatures, and since it's a vital part of the global food network, these climate changes have far-reaching global consequences (Dawson et al., 2016). Changes in global temperatures and precipitation patterns impact food production, processing, and quality. Rising sea levels and extreme weather events due to climate change further hinder the global transportation of food (Dawson et al., 2016). Based on worst-case greenhouse gas emissions and population growth, the USDA predicts that the number of undernourished people worldwide could increase by 175 million by 2080 (Dawson et al., 2016). China, as the world's most populous nation and one of its largest greenhouse gas emitters, faces complex challenges related to climate change and food security. With a growing population and a significant agricultural sector, China's ability to feed its people is crucial. The country is experiencing shifts in temperature and precipitation patterns, which impact crop yields. This is evident in regions such as Northern China, which has seen decreased wheat production due to water scarcity caused by changing climate conditions (Tao et al., 2014). Climate adaptation strategies and investments in more resilient crop varieties are crucial for China's food security (Zhang et al., 2019).

Germany, a leading European country, is also affected by climate change, which poses challenges to its food security. While Germany has a highly advanced agricultural sector, it is not immune to the impacts of a warming climate. Changing rainfall patterns and an increased frequency of extreme weather events, such as heavy rainfall or droughts, can disrupt crop production and impact food availability. Recent studies in Germany have shown that climate change can lead to a reduction in crop yields for wheat, maize, and barley (Reckling et al., 2016). Adaptation measures, like precision agriculture and the cultivation of more drought-resistant crop varieties, are necessary for Germany to secure its food supply in a changing climate. Climate change poses a significant threat to food security in Africa, impacting both agricultural production and food availability. For instance, in Kenya, rising temperatures and erratic rainfall patterns have led to reduced crop yields and increased vulnerability among smallholder farmers, who make up a substantial portion of the population (Nyangena et al., 2019). This is exacerbated by extreme weather events such as droughts and floods, which disrupt farming activities and further compromise food production (Mugo et al., 2020). Additionally, the changing climate has resulted in the expansion of pests and diseases, which threaten staple crops like maize and beans (FAO, 2016). To address these challenges and enhance food security, comprehensive adaptation strategies and policies are crucial in Kenya and across Africa.

Climate change is a key concern within South Africa. Mean annual temperatures have increased by at least 1.5 times the observed global average of 0.65°C over the past five decades and extreme rainfall events have increased in frequency. These changes are likely to continue: the 2013 South African Long Term Adaptation Scenarios and the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5) for Representative Concentration Pathway (RCP) 8.5 suggest warming relative to 1986–2005 of 3–6°C by 2081–2100 in the interior, yet less certain precipitation changes in terms of both direction and magnitude. Climate change poses a significant threat to South Africa's water resources, food security, health, and

infrastructure, as well as its ecosystem services, and biodiversity. Considering South Africa's high levels of poverty and inequality, these impacts pose critical challenges to national development (Barange et al., 2018).

According to Morin (2014), food security refers to a condition where all individuals within a community, region, or nation have consistent and reliable access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life. It encompasses not only the availability of food but also factors like accessibility, affordability, and utilization. In contrast, food insecurity refers to a state where individuals or households lack consistent access to enough food due to various socio-economic and environmental factors, often leading to hunger, malnutrition, and uncertainty about future food availability (Saint Ville et al., 2019). Food insecurity can manifest as mild, moderate, or severe, with individuals experiencing varying degrees of vulnerability to hunger and inadequate nutrition. Addressing food insecurity is essential for ensuring the well-being and health of populations worldwide (Saint Ville et al., 2019). The United Nations Food and Agriculture Organization (FAO) estimates that nearly 900 million people on the planet are suffering from chronic hunger. This state of affairs led to the making of the United Nations Millennium Development Goals in 2000, having the first goal to "Eradicate extreme poverty and hunger" with a target of halving the proportion of people who suffer from hunger. However, projections of a rapidly growing population, coupled with global climate change, are expected to have significant negative impacts on food security. Under a no-climate change scenario, based upon projected changes in population and agricultural land use only, results show that 31 % (2.5 billion people by 2050) of the global population is at risk of undernourishment if no adaptation or agricultural innovation is made in the intervening years. An additional 21 % (1.7 billion people) are at risk of undernourishment by 2050 when climate change is considered.

5 METHODOLOGY

An explanatory case study was a suitable research approach for investigating the impacts of climate change on food security in Enyezane, KZN, given the complexity of the topic, the need for in-depth understanding, and the qualitative nature of the research objectives. It enabled the exploration of the specific context of Enyezane and provided valuable insights into the issues at hand. A qualitative research apporach was employed through the use of semi-structured interviews which allowed the researcher to gain an in-depth understanding of the local context, including the specific socio-cultural and economic factors that influenced food security in Enyezane. Through interviews and observations, researcher captured the diverse experiences and perceptions of community members. Purposive sampling was used to select 20 participants that include local farmers, livestock owners, and residents who had experience dealing with climate-related challenges in Enyenazane who provided valuable insights into the research based on thier knowledge and experience of climate change and food security in the region. The study was conducted from March 2023 until the end of November 2023.

6 RESULTS AND DISCUSSION

6.1 Extreme weather events: droughts and floods

The study revealed that climate patterns in Enyezane have undergone significant changes in recent years. Respondents consistently reported alterations in the timing and intensity of seasons. One participant noted, “We used to have predictable seasons, but now it is all unpredictable. Sometimes, we experience summer-like temperatures during what should be the rainy season.” This unpredictability in climate patterns has raised concerns among the local population. The alteration of climate patterns observed by respondents highlights the need for adaptive strategies in Enyezane. These changes could potentially disrupt traditional agricultural practices and food production systems, thus impacting food security in the region. Respondents overwhelmingly identified extreme weather events, particularly droughts and occasional floods, as major climate-related challenges in Enyezane. A participant expressed, “Droughts have become more frequent and severe. We struggle to grow crops, and our water sources are drying up.” These events were often cited as causing food shortages and economic hardships. The recurring droughts and occasional floods in Enyezane are clear indications of climate change impacts. These events pose significant threats to food security, as they disrupt agricultural activities and access to clean water. Effective mitigation and adaptation measures are essential to address these challenges.

Another challenge is that the community of Enyezane rarely get notifed by the municipality of predications on extreme weather. One of the participants mentioend that “we rarely receive timely warnings about extreme weather events. When floods or storms hit, it is often too late to protect our homes and crops." This lack of early warning systems contributes to increased vulnerabilities. Another respondent mentioned, "after disasters strike, we struggle to get help. Emergency response teams are ill-equipped and understaffed, making recovery slow and difficult." The inefficiency in disaster response further compounds the challenges faced by the community. A community member stated, "Our roads and bridges are not built to withstand extreme weather. When they get damaged, it disrupts the movement of goods and services, affecting our livelihoods."

6.2 Water scarcity

Participants emphasized the growing problem of water scarcity and the need for improved irrigation practices. One of the participantsoutlined the following, “Access to water for irrigation is a constant struggle. Our local rivers are drying up, and the cost of drilling boreholes is prohibitive for many small-scale farmers like me.” Another participant stated, “Efficient irrigation systems are the need of the hour. Climate-smart irrigation methods can help us make the most of the limited water resources we have left.” These statements highlight the urgency of addressing water scarcity issues and implementing sustainable irrigation solutions in the face of climate change. Such efforts are crucial for ensuring food security in the Enyezane area.

Water plays a crucial role in agricultural activities in rural households (Wani et al., 2009). However, decreased rainfall during periods of drought have already caused agricultural yields to decrease in some parts in South Africa (Dalin and Conway, 2016; Funk and Brown, 2009). Additionally, drought conditions further exacerbate poverty in areas experiencing soil erosion and land degradation. This is as a result of a relationship that exists between land degradation and drought (Wani et al., 2009). The effects of the current drought are seen in a small farm in the Enyezane community. The lack of water resources in this community have resulted in low agricultural yields which have hindered farming activities in some households. Other households have sized production of certain crops which intake much water such as spinach and cabbage.

6.3 Crop yield variations

Findings from the study indicate that climate change has had a significant impact on crop yields in the Enyezane area, KwaZulu-Natal. Respondent stated, “Over the past few years, we have e seen unpredictable weather patterns affecting our maize and bean crops. Sometimes, it is prolonged drought, and other times, it excessive rainfall. It is become increasingly challenging to predict our harvests.” Another respondent added, “The changing climate has made it difficult to rely on traditional planting and harvesting times. We often have to adjust our planting schedules, and this uncertainty affects our overall crop production.” These responses illustrate the consensus among respondents about the adverse impact of climate change on crop yields. The unpredictability of weather patterns disrupts traditional farming practices and jeopardizes food security in the region.

6.4 Livestock production challenges

The study found that livestock production faces numerous challenges due to climate change. Respondent highlighted, “Our cattle and goats are struggling to find enough pasture due to prolonged dry spells. We have also seen an increase in disease outbreaks, which we suspect is linked to changing weather conditions.” Another respondent added, “my cattle have tick-borne, and I do not have medicine that I can use to treat it”. Another affected respondent mentioned, “Extreme heatwaves are stressing our poultry, leading to lower egg production. We are also concerned about the availability of water for our animals during droughts.” Livestock farmers in the Enyezane area have faced substantial challenges due to climate change. Respondents reported that increased temperatures and prolonged droughts have stressed their animals, leading to reduced livestock production. One respondent mentioned, “Our cattle used to be healthier, but now, they suffer from heat stress and lack of water, affecting milk and meat production”. This results in a shortage of food because most people in the community rely on cows for milk, meat, leather, and hundreds of other products that people use in everyday life.

Another growing concern that was raised on account of the extreme weather events in the area was the increased cases of ‘tick-borne’which are small arachnids that feed on the blood of mammals, including cattle.

They attach themselves to the cow's skin and feed on its blood, which can lead to various health problems for the cow. The cow usually ends up dying because of it. One of the respondents who is an owner of livestock highlighted that he has noticed that tick populations often vary with the seasons. He further outlined that in this area, ticks increase during the spring and summer months when temperatures are higher and humidity levels rise. The tick-borne challenge is further eccerbated by the water shortages experienced in Enyazane as one of the farmers indicated that "I cannot go to Endiphini (Endiphini is where tick-borne disease is treated with some chemicals) because there is no water and the river is far". These responses underscore the multifaceted challenges faced by livestock farmers in the Enyezane area. Climate change-induced factors like reduced pasture and heat stress not only affect livestock health but also jeopardize the livelihoods of farmers.

6.5 Adaptation strategies and practices

Several participants that were interviewed highlighted their practice of retrieving water directly from the nearby river or through rain water harvesting which they stored in large containers called "Jojo tanks" that hold up to 5,000 litres of water and were kept for the purposes of irrigation or household tasks. This diligent process underscores their commitment to sustaining their agricultural endeavours through resourceful water management." We store rainwater in the Jojo tanks or during times when the rivers arent dried up, we get water from the river and store it so that we are able to still water our crops using water cans".

Another strategy that has been employed is during the extreme winter months, in the absence of a broiler, chickens are sensitive to cold temperatures, and prolonged exposure to low temperatures can lead to cold stress. This can result in reduced egg production, decreased feed consumption, and overall poor health. Livestock farmers have employed the ingenious "iMbawula" method, to create a cozy and comfortable environment for her cherished chickens amidst the chilly winter season. This implies building a round metal container and lighting up some fire wood inside of it which then produces heat for the chicken (see figure below).

Fig. 2: iMbawula to keep her chickens warm and comfortable during the cold winter.

Due to the uncertainty of the climate and the impacts on agricultural activities in Enyezane, another strategy employed is livelihood diversification where communty members and farmers are exporing different ways to generate and income to sustain their livelihoods such as firewood trading and petty trading such as selling of vegetables, fruits, sweets among other things. Diversification was also witnessed in the crops as the community is increasingly moving to drought-resistant crops such as sorgum to counter food security challenges posed by the change in weather. One participants explained that "I told my family that we can't just stick to maize for porridge anymore because the maize crops aren't doing well. So now we're trying out other crops like sorghum, and they seem to be handling the heat better."

The reliance on social networks in the community was also another strategy used to cope with the effects of climate change. Some participants mentioned that many community mambers would come together to provide support in the form of vegetables and maize in the times when other community members were not able to provide for their own household. One partisipant incated " if my crops are not able to yield any fruit, I know that my neoghbours will suport me. We support each other in this community because we all know that

these things are unpredicatable and tommorrow it could be you in the same situation so we come together and assist each other with some veg or maize when its really bad". There is also an increased reliance on the govenrment support. This was evident in the participants in the study identified the importance of government support programs in mitigating the impacts of climate change on food security in Enyezane. They emphasized the need for targeted assistance to those most affected by climate-related challenges. Respondent stated, "Government support programs are a lifeline for us. They provide food and resources during times of drought and extreme weather events. Without them, many families would suffer even more." Another respondent mentioned, "These support programs need to be more accessible and better advertised. Many people in our community do not know about them, and that needs to change." The respondents' recognition of the importance of support programs highlights the vital role of government in addressing food security challenges in Enyezane. It's evident that while these programs exist, there is room for improvement in terms of accessibility and awareness.

A crucial response to the urgent problem of food scarcity within the Enyezane community, brought about by the extensive repercussions of climate change, is the implementation of a Government Intervention food parcel program. This essential initiative is designed to offer assistance to individuals and families who have been severely affected by the far-reaching consequences of environmental shifts. Its primary objective is to strengthen food security for those grappling with the profound challenges posed by climate change, ultimately ensuring their sustenance and well-being in the face of ongoing environmental challenges.

7 CONCLUSION

In conclusion, the primary objectives of this study were to investigate the impacts of climate-related shocks on food security within the Enyezane community, exploring the coping strategies employed by residents to address food insecurity. The study uncovered significant insights into the experiences of the Enyezane community with climate-related shocks and food insecurity. The findings indicated that climate-related stocks, such as extreme weather events and changing rainfall patterns, have had adverse effects on food security in Enyezane. These shocks disrupted agricultural activities, reduced crop yields, and compromised the availability and affordability of food, thereby exacerbating food insecurity in the community. In response to these challenges, the Enyezane community employed a variety of coping strategies. These strategies included diversifying livelihoods, reliance on social networks for support, and the use of government assistance programs. These efforts demonstrated the resilience and adaptability of the community in the face of food insecurity threats. This research underscores the pressing need for a comprehensive approach to address food insecurity in Enyezane, considering climate resilience, community empowerment, and urban planning integration. Implementing these recommendations can contribute to building a more food-secure and resilient Enyezane community in the face of climate-related challenges.

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Climate Resilient Sponge Cities – Concepts and Tools to Integrate Green-Blue and Grey Systems

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1 ABSTRACT

Climate hazards from increased frequency and severity of extreme weather events require urgent urban adaptation action to increase resilience against flooding, landslides and extreme urban heat, as some of the highest risks. Nature-based solutions (NbS) in the form of functional urban green can effectively reduce disaster risks (IUCN, 2020; L. Arjan et. al., 2021). Ideally such green-blue infrastructure would form networks and be systemically integrated with gray infrastructure like drainage pipes to optimize resilience against flood risk. This paper looks at the Sponge City program in the People's Republic of China (PRC), which incorporates a range of water-related nature-based solutions to manage natural water cycles in cities and reduce urban runoff and flood risk, locally capturing, retaining infiltrating, and harnessing rain- and stormwater reused as water resources, increase local natural infiltration and threrby also cleaning stormwater. Technical guidelines were issued and 30 pilot cities were supported in 2015 and 2016, followed by 60 demonstration cities in 2021 and 2022 (Ministry of Housing and Urban–Rural Development, 2014). The key indicator set by the government has been to capture 70% of annual rainwater in the pilot areas. A recent study suggests that this has been achieved in the three cases used (J. Wu, 2022).

While this concept is not new, it is now being applied by an increasing number of cities around the world using this name (for eaxample: Hamburger Stadtentwaessering, 2015). Sponge cities in the PRC and elsewhere should be mainstreamed and better integrate with gray infrastructure to be most effective and efficient resilience systems to reduce flooding and extreme heat while also delivering a whole range of other ecosystem services as co-benefits, including contributions to climate change mitigation (for example: G. Browder et al. 2019). Not least public health, recreational benefits and land value increase can be captured. Planning and implementing green-blue systems as retrofitting of existing urban areas is challenging and requires strong stakeholder and community participation. Mainstreaming NbS and sponge cities as part of risk-informed and integrated urban and regional planning of new urban areas in urbanizing Asia and Pacific and Africa is essential considering the reality of rapid temperature increase and increased climate variability. The Asian Development Bank (ADB) is committed to be the climate bank for the Asia and Pacific region. ADB supports, among others, green city development, climate risk assessment, resilience investments inclusive of NbS and sponge cities, and contributed with advancing methods and pilot projects (ADB, 2016a, 2016b and 2019).

This paper offers an overview of sponge city in the PRC, technical and policy dimenions and initial observations on strengths and weaknesss of implementing the 30 plus 60 pilot and demonstration cities. A key conclusion is: it is essential for cities to establish effective green-blue NbS resilience systems. Effective gray engineeering infrastructure systems in cities are very much also needed. Systemically integrating both, green-blue and gray systems is essential to delivers best results. With the required urgent comprehensive transformation, all needs to be planned well across sectors, to ensure that investments in NbS contribute simultaneously to both, mitigation and adaptation. And it is critical that planning integrates with other objectives inclusive of compact city, healthy and age-friendly city, among others (N. Habib et.al., 2020) Because physical structures, industries, standards, governance, regulatory and educational institutions, and mindsets can't change overnight, a holistic strategy and the collective will to fast forward implementation is most needed. Some of the below findings were described in a prior publication by the author (S. Rau, 2022) and updated with results from new literature and projects, especially on effectiveness evaluation and new methods applied.

Keywords: risk-informed planning, advanced planning tools, sponge city, nature-based solutions, urban climate resilience

2 THE CHALLENGE: CLIMATE CHANGE RISKS TO CITIES

Cities and their residents are most affected by the fast changing climate and they also significantlty exacerbate its adverse impacts from its carbon emissions. East Asia is expected to be disproportionally more affected by climate impacts compared to global average. Weather extremes will be more likely and frequent, including torrential rains, cyclones, lomg dry periods and heat waves, that cause flooding, landslides, desertification, sea-level rise, drought and extreme urban heat (IPCC, 2021). At risk are human lives and health, livelihoods, families' life savings, infrastructure and assets. Disasters are exacerbated by unsuitable land use and urban form, i.e., in areas at risk of exposure to hazards and as carbon-intensive urban patterns and economies. Paved land and buildings generate stormwater runoff that requires management and they absorb and store heat.

Densely built-up urban areas without or with limited green spaces are up to 10 degrees hotter in the summer. This has already claimed premature deaths in many cities including in high-income countries and is a significant risk in developing economies. Vulnerable social groups are more affected, including poor, low-income and elderly people, which requires adaptation to be inclusive. Urban investents, public and private must contribte to the dual transformation need of resilience and low-carbon development.

Existing cities and urban areas require comprehensive and fast adaptive retrofitting action (S. Rau, 2021). This is a prime task around the world, and it is the most challenging. It requires participation and new forms of partnership among adinistration, communities, businesses and individuals. It involves risk analysis, planning, design and orchestrated public and private investment planning and careful implementation. A key obective is to establish effective resilience systems (while also reducing carbon emissions) covering the whole urban territory of an urban region and reaching beyond for building effective ecosystem networks. Newly developed urban areas in rapidly urbanizing regions especially in south and south-east Asia and in Africa require practical methods for risk-informed integrated urban planning aiming at comprehensive resilience - as well as low-carbon, resource-efficient development. Concerted swift transformation is challenging in all aspects, institutionally, technically, societal, economical and financial.

3 CONCEPTS AND INSTRUMENTS: NATURE-BASED GREEN-BLUE INFRASTURCTURE

Urban resilience through nature-based solutions (NBS) can be an effectice, efficient and widely accepted approach and applied through the sponge city concept in its comprehenive understanding. A sponge city soaks in rainwater and retains excess stormwater, then filters and releases the cleaner water slowly, much like a sponge does. A sponge city aims at improving urban rainwater management reducing runoff from bildings and paved areas and increase retention and natural infiltration applying nature-based solutions and green-blue infrastructre (i.e. K. Yu, 2016). NbS applied in sponge cities include preserved floodplains, stormwater retention lakes and ponds, wetlands, greenways, parks, rain gardens, green roofs, and bioswales. And also pervious pavement and underground water storages are applied. A comprehensive city-wide and river-basin wide plan for sponge city would deliver both resilience to various climate risks and simultaneoulsy contribute to climate mitigation.

Cities require both structural measures, like gray and green infrastructure system investments, and non-structural measures, like disaster preparedness and early warning systems for floods and other potential disasters (United Nations Office for Disaster Risk Reduction, 2015, 2019). Structural measures have traditionally been gray infrastructure, e.g., concrete walls, dykes, drainage pipes, canals, deep tunnel systems and large storage tanks.

Natural green-blue systems and their self-regulating capacity have been rediscovered as effective resilience measures and have been applied as ecosystem-based adaptation in more and more cities around the globe (for example: European Commission, 2015; UN Water, 2018). In the People's Republic of China (PRC) the concept of sponge cities is based on NbS and green infrastructure. It has been a national government program supported by the Minsitry of Housing and Urban-Rral Development since 2014 through 30 pilot cities (an evaluation was done by D. Yin et al, 2020). Support continues with a more systematic and systemic approach and as better intregration of green-blue and gray systems for additional 60 demonstration cities since 2021. Outside the pilot cities program every city in the country was obliged to prepare and implement sponge city masterplans.

Further integration with the objective of low-carbon and comprehensive climate-resilient development is critical for resource efficiency and can be achieved though systematic urban planning, urban design, and integrated investments. Systematic urban planning and urban design can take into account the needs for both low-carbon development and risk-informed planning for resilience against more natural hazards in a changing climate that will impact the PRC disproportionally more than other regions (IPCC, 2021, World Bank and ADB, 2021). Integration will effectively avoid redundant constructions and deliver more value and benefits for each dollar invested, as opposed to scattered unintegrated sector-wise investments. This will promote long-term sustainable green transformation. Planning of urban patterns with compact mixed-use development based on public transport, walking, and cycling with small blocks and small streets and public green spaces will reduce the need for transport as people may choose to live near where they work, shop, and go for recreation in parks.

PRC's Technical guidelines for Sponge Cities provide a catalogue of NbS options. The Ministry of Housing and Urban–Rural Development published Technical Guidelines for Sponge City Construction in 2014. These comprehensive guidelines instruct cities to assess and plan a comprehensive sponge city approach on integrating all levels of planning and design, from strategic urban and regional planning to detailed community, site, road and building design, construction, and maintenance. The overarching principle is low-impact development, conservation and protection of rivers, wetlands, and other water-related and green-space ecosystems; the enhancement of the hydrological functions of these areas; and the integration of them into urban areas. The overall national target of an 80% reduction of urban runoff is regionally differentiated according to precipitation levels and overall very ambitious. The guidelines recommend specific measures that should be considered and integrated, such as permeable paving, green roofs, sunken green spaces, biological retention facilities, infiltration, wet and regulating ponds, seepage wells, rainwater wetlands, rainwater tanks, conditioning tanks, grass ditches, seepage pipes/drains, vegetation buffer zones, initial rainwater abandonment facilities, and engineered soil infiltration enablers. Sponge city program is not isolated. It is embedded within a range of policies. It is aligned with the national adaptation strategies of the PRC (Government of the PRC, 2013 and 2022). And it aligns with the PRC's urban adaptation action plan (Government of the PRC, 2016).

Systematic, intergated multi-scale planning and scenario comparison. A comprehensive approach involves intergated risk assessment and risk-informed urban and regional planning on watershed, urban region, city, district and neighborhood scales. It considers natural and manmade systems like surface and groundwater, existing topography and forests, green spaces, as well as land cover, land use and built infrastructure and assets. As a key feature of sponge city planning is decentralization of drainage aiming at local rainwater retention and infiltration, cumulative local action in many places can contribute significantly to reduce flooding of the drainage system, while local actions also need to be part of a larger hydrological system and climate system for cooling effects.

Advanced planning and simulation tools. The use of locally shared GIS platforms with data-feeding and use by local administration and researchers across sectors offers many opportunities to analysis and applying science to planning and action. Climate models that localize global and regional models allows better understaning of local hazard risks. The use of tate-of-the-art hydrological and hydraulic modeling allows comparative assessment of planning scenarios to guide policy makers on most effective and efficient adaptation options. Local climate and wind models help understand areas of high risk to extreme urban heat and allow conceptualizing systems of cool air pathways for natural ventilation of cities. Their comprehensive integration enables optimization of green-blue system layout for reaping most benefits from available land and financial resources. They are useful instruments in the process to promote the best solutions in the consultation and participation process.

Optimize multiple ecosystem-service benefits from NbS through systematic planning and design. Results from implementing integrated sponge city concepts on the ground start to show improved resilience against urban flooding and water scarcity, as well as additional benefits from ecosystem services like reduced heat in the summer, enhanced biodiversity, improved livability - and increased land value. Studies show that residents welcome actions for reducing risks and for their increased urban liability from the green spaces, green roofs and facades etc.

Optimize resilience improvement from systemic integration of green-blue and gray systems. The sponge city program in the PRC has been improved to deepen and better integrate gray and green measures so they mutually reinforce one another and work as optimized system together. Existing gray infrastructure systems like drainage pipe networks were analyzed and assessed for improvement opportunities, i.e. along with other system improvements, like separating existing combined sewers into sanitary sewers and drainage pipes. Drainage pipes can be more directly discharing stormwater into rivers, as opposed to the detour through the wastewater treatment plant. This results in more effectiveness and efficiency. The more polluted first flush of the stormwater can be cleansed through NbS as guided into sand and earh filters before discharging into the river. Integrating this with comprehenive stormwater retaining cascading at-grade green-blue systems showes in digital simulation that urban flooding can be very significantly reduced in the future. What is true for reduced floood risk is also true for impproved water management for irrigation and for improved urban microclimate and the carbon sequestration and air quality improvement impacts.

4 PROJECT CASES: PILOTS ADVANCING METHODS AND TECHNIQUES

There are many cases in the PRC – and also elsewhere as the concept is applied in many places, that have been studied and evaluated. A few have been supported by the ADB in the PRC, including in Jiangxi Pingxiang, Jilin Yanji and Shanxi Changzhi. They were also used to advance methods and techniques. For eample, digital analysis tools of hydrological and hydraulic models linked with GIS were used to develop and simulate scenarios for design storm events and drainage design scenarios. Gray and green-blue infrastructure systems were integrated and simulated together. Ecological river rehabilitation and flood risk management preserving floodplains and rehabiliting wetlands for water retention and cleansing and biodiversity enhancement. Other measures include instream river training for flow management and reduce pressure on embankments. Further measures include design of cascading systems of green roofs, rain gardens, bioswales, earth filters and wetlands for first-flush stormwater treatment.

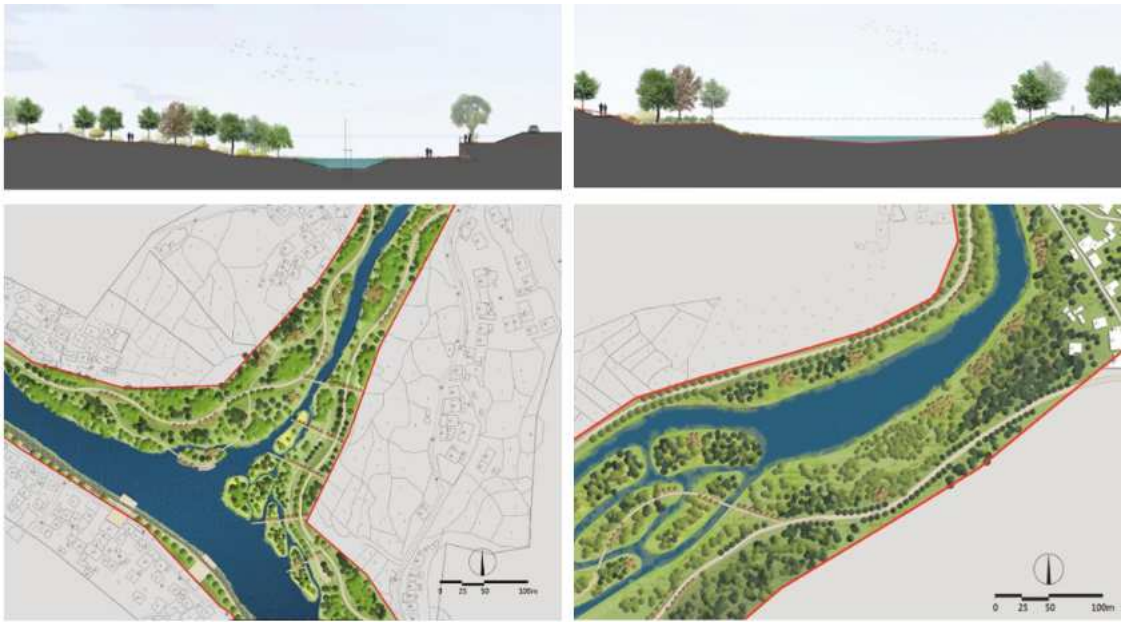
Jiangxi Pingxiang Intergated Rural-Urban Infrastructure Development Project Case: Flood risk reduction is a top priority in Pingxiang, in Jianxi Province of the People's Republic of China. Flood frequency and severity have increased significantly since 1998. Floods in 1998, 2001, 2002, 2010, and 2014 affected more than 496,000 people, caused the collapse of more than 2,600 houses, and resulted in significant economic losses in agriculture. A major flood on 25 May 2014 severely impacted public safety and health and caused an estimated $115 million in economic losses. As a headwater municipality where all rivers originate within its territory, Pingxiang is prone to fluvial flooding, a key risk aggravated in combination with pluvial flooding in urban areas. Most riverbanks in Pingxiang have inadequate flood protection, sediment accumulation from riverbank erosion, and raised riverbeds from mining sediments, further reducing the flood discharge capacity of rivers. Urban drainage systems, the gray infrastructure, in Pingxiang are made of combined sewer and drainage pipes. These challenges were addressed by an ADB supported project (ADB, 2015).

Pingxiang was selected as one of 16 first generation national pilot sponge cities in 2015. ADB prepared and supported a project that contributes to making the sponge city concept more comprehensive and greener. The ADB project contributes with the river related infrastructure to Pingxiang's Pilot as an overall strategy by piloting sponge city design principles and green infrastructure development in the four key sub-centers and the respective urban and river areas of influence of Pingxiang Municipality in Xiangdong District urban center, Lianhua County (county seat), Luxi County (county seat) and Shangli County (county seat and Tongmu township), while the national government program focused on areas in Pingxiang's core urban area. It consolidated planning and investment for integrated river rehabilitation and flood risk management to improve climate resilience, enhance biodiversity, and contribute to urban greening as an amenity for citizens, thereby increasing livability and value of a city. The various features include green embankments, publicly accessible river greenways, floodplain protection, wetland rehabilitation, and wetland parks for stormwater retention, as well as sewer and drainage separation and wastewater interceptor pipes along project rivers.

The project changed the conventional gray infrastructure approach of flood control through channeling the river with walls and/or hard embankments to a green infrastructure ecosystem-based adaptation approach. More green space is provided to the rivers. Floodplains and wetlands are maintained and/or rehabilitated, and green embankments with soft water edges are applied to allow for natural and seasonal fluctuations in water levels and to reduce flooding impacts of more frequent and severe storm events, while also contributing to enhanced ecology and water quality. Climate risk and vulnerability assessment and hydraulic modeling of

anticipated storm events were developed during the preparation of the project. Specific additional adaptation measures were included in the design. During the implementation of the project lessons learnt were applied in new subproject designs and replicated in other locations. Lessons were also shared with others in the country for replication. Below are sample design illustrations and pictures of the implemented project. Local residents and visitors already enjoy the river greenways and reduced flooding, and the government benefits from increased tax revenue of increased property values and more people and businesses attracted to the greener towns.

Aerial Foto of a completed wetland restoration that doubles as urban park for recreation and for improving microclimate in Pingxiang. Source: Pingxiang Government.



Design of green embankments, riparian landcape and rehabilitated wetlands with increased flow capacity and enhanced biodiversity. Source: ADB consultants for Asian Development Bank.

Jilin Yanji Low-Carbon Cimate-Resilient Healthy City Project Case: For this project, ADB used the design of sponge cities as a platform for mitigation and adaptation elements, such as public transport to promote walking and cycling and healthy lifestyles (ADB, 2019). It further piloted innovative approaches, including advanced computer modelling, demonstrating that integrating green and gray infrastructure can significantly reduce urban flooding (pluvial flooding).

Flooding is a significant problem during the rainy season in June and July. Flooding occurs for about 5 days per year on average in recent years. River flooding, flash floods, and urban flooding endanger lives, property, and livelihoods, and disturb traffic and public life. The combined sewer and drainage pipe system is outdated. Only 11.6% of the pipe network meets the required 1-in-3-year flood design standard, causing pluvial flooding during heavy summer rains. The Chaoyang River urban catchment area is currently exposed to flood risks of 1-in-20-year flood events.

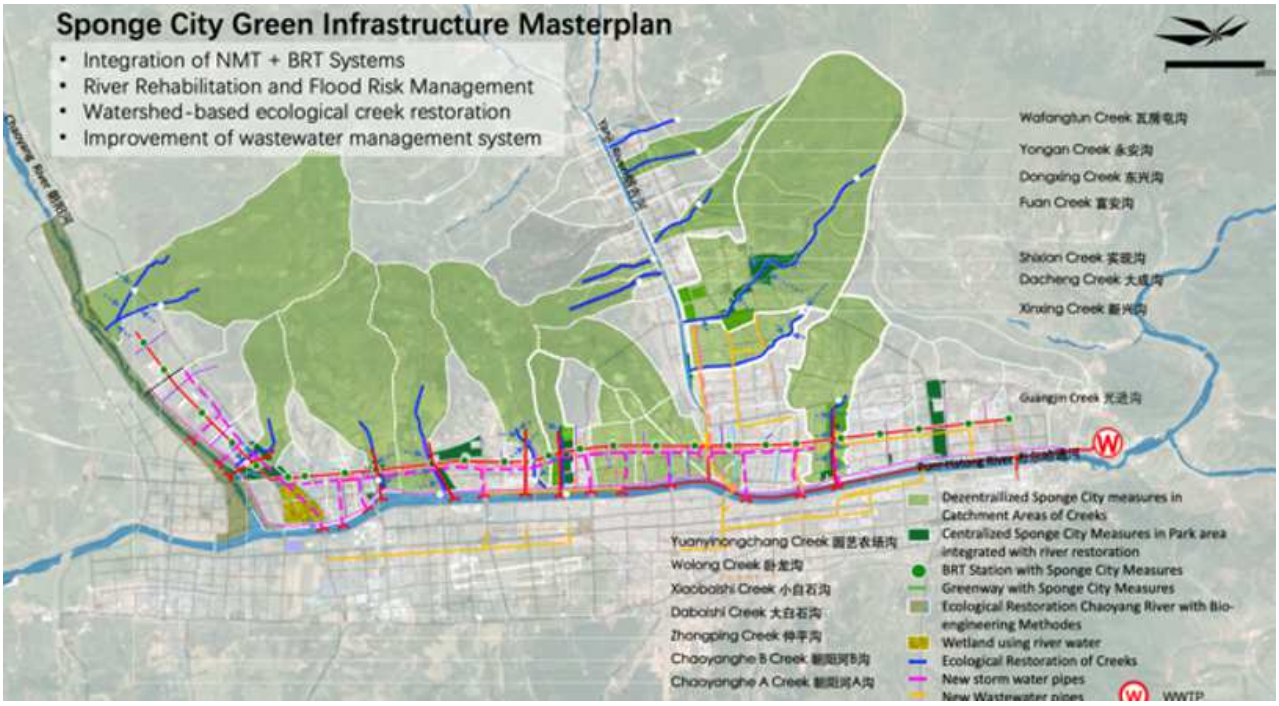
Flood risk reduction. Restored riverside wetlands and green water edges along gentle slopes along the river reduces the risk of flooding. At the same time, they provide a habitat for a diversity of plant and animal species and serve as an amenity for residents during non-flood times. (Photos: Stefan Rau) Source: Asian Development Bank.

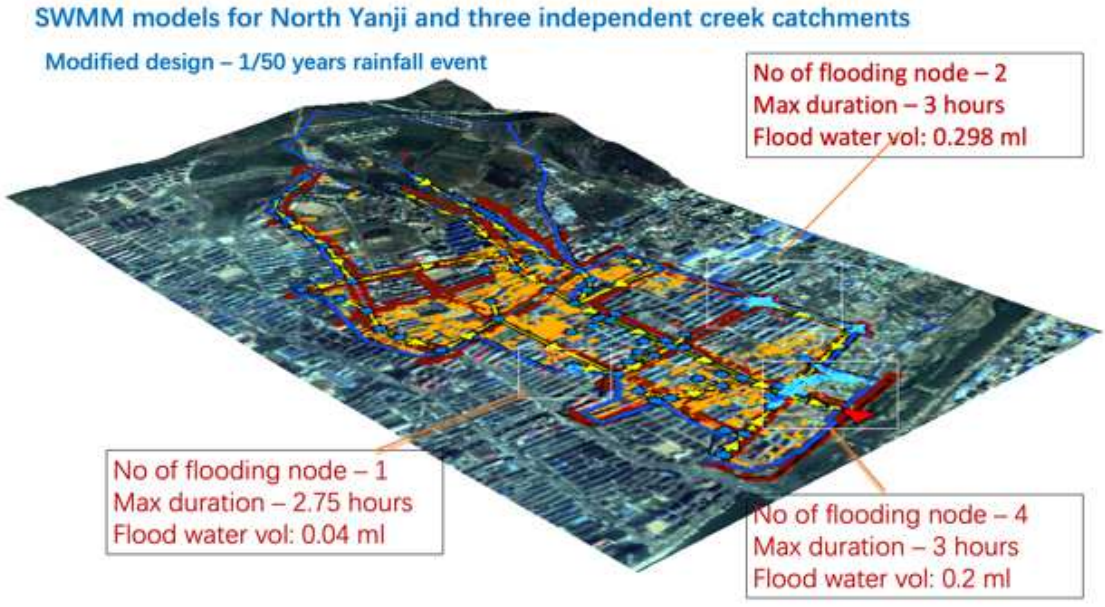
ADB financed the first bus rapid transit (BRT) corridor in the northeast of the PRC and integrated it with comprehensive stormwater management and water supply system improvements. The overall concept follows the principles of transit-oriented development, focusing on higher density mixed-use and pedestrian-friendly center areas including green spaces around BRT stations, thereby promoting low-carbon urban mobility. New green spaces that are designed as sponge city green infrastructure will link station areas with project-supported riverfront greenways. These spaces will create a network of sponge city infrastructure enhancing climate resilience and urban livability. These green spaces apply universal design principles to ensure accessibility and also promote healthier lifestyles for residents and tourists, hence contributing to a healthy and children and age friendly city development.

During project design, a catchment-based sponge city master plan for the northern part of the city was developed along with a climate risk and adaptation options assessment. A detailed digital topographic urban and hydraulic model was developed for the project. The model was piloted as an expert tool that simulates future storm scenarios and adaptation options integrating existing and newly proposed drainage pipe network improvements with at-grade sponge city green infrastructure. Improvements to drainage and flow capacity, combined with increased stormwater retention and infiltration capacity, were quantified, visualized, and evaluated to optimize flood risk reduction, investments, and green space benefits. Investments include sponge city green infrastructure along streets with permeable paving and tree plantings in large planters with increased space for roots and more infitration capacity. It includes rain gardens and bioswales in residential areas within the catchment of creeks, integrated with improved and separated drainage pipes (at least 43 km) and wastewater pipes (at least 40 km), using results from a detailed integraeted 3D hydraulic modeling. The project significantly reduces the climate-related pluvial and fluvial flood risks (according to the project's hydraulic model up to 1-in-50-year flood events). It also improves the water quality through the construction of end-of-pipe sedimentation tanks and reed-bed sand filters. Fluvial flooding is reduced through ecological river rehabilitation of the Chaoyang River, improving the flood protection standard from 1-in-20-year floods to 1-in-50-year flood events. Bio-engineering is adopted, which includes in-stream solutions in the riverbed

and green embankments as well as building pedestrian and bicycle paths with tree planting along the greenway.

This intergation of improving gray drainage pipe systems by short and direct alignments to the river with end-of-pipe solutions and the systemic integration with newly introducded above-grade and at-grade green-blue measures retaining and cascading stormwater effeectively reduces urban and river flood risk. The benefits of improving public transport, linking with expanded bicycle and pedestrian networks and green spaces are already transforming the city. The BRT system is a great success with ridership of public transport significantly increased and pupulating the enhanced and new functional green spaces. Below are planning diagrams and the visualization of the system.





Sponge City Green Infrastructure Master Plan for Yanji City. (Plan graphics is based on river and creek catchment areas for the area north of the Buer Hatong River, image by Nengshi Zheng, SWMM model image by Heping Zuo). Source: Asian Development Bank.

Shanxi Changzh Low-Carbon Climate-Resilient Circular Economy Transformation Project Case: Changzhi was selected as a national demonstration sponge city in 2021 for deeper application of the concept. ADB prepared an integrated support project. Changzhi is located in southeast Shanxi Province and is part of the Yellow River Ecological Corridor, which had a total population of about 160 million in 2021. Changzhi's

permanent resident population grew to 3.15 million in 2021, with about 899,000 living in the center area of the municipality's urban districts. Similar to most of Shanxi Province, the economy is dominated by carbon-intensive heavy industry, such as coal and energy; this impacts Changzhi's air quality, which is slightly worse than other cities of similar size. Heavy industry generates about 77% of the city's total revenue but employs only 11% of the workforce (ADB. 2023).

Implemented first phase of the bus-rapid transit with bike paths and sponge city tree planting and road median landscape linking to green parks. Source: Yanji City Government

Annual rainfall in Changzhi is low (534 millimeters), with more than 60% falling in summer. Groundwater resources are widely used. Changzhi is exposed to wildfire, drought, and seasonal flooding risks, all of which will be exacerbated by climate change. By 2050, the average temperatures in Changzhi are expected to increase by 2.3˚C, which will likely cause a potential increase in evaporation. The changing climate will also increase extreme weather events, with long dry periods and heavy rainstorms, and increased water scarcity, droughts, and floods. Continued groundwater use has caused a significant depletion in the water table, which has dropped by more than 10 meters in some areas since 2000. In Qinyuan and Licheng counties, recent floods damaged riverbanks with over 300 households significantly affected. Changzhi's institutional capacity on climate-resilient planning and green financing are weak and fiscal resources are limited. Lack of cross-sector coordination within the government along with a lack of information and communication technology (ICT) platforms hinders the modernization of governance. Poor urban and transport planning have resulted in climate-vulnerable urban patterns.

The project carried out climate risk assessment and proposed and included adaptation measures to reduce the risk of flooding, drought, urban heat, and wildfire. The main approach is applying nature-based solutions using green infrastructure while also improving gray infrastructure systems and systemically integrating both to manage climate-related risks. These physical measures are complemented with non-structural measures like monitoring and early warning systems, disaster risk preparedness, and institutional capacity building to further plan for resilience and effective management inclusive of insurance schemes will increase Changzhi's resilience against climate-related risks.

The project provides strengthening of government institutions and engaging the private sector to transform a carbon-based economy toward a low-carbon and zero-waste resilient city and contributing to climate resilience and building green capital through integrated planning and by implementing compact city and transit-oriented development principles with pedestrian-friendly green urban environments. The project reduces waste and explores lifecycle assessment to further reduce environmental impacts, reduces carbon

emissions, and optimizes resource use efficiency. The sponge city contributions of the project include new green parks to function as flood retention areas as well as cool air pathways to reduce extreme urban heat. These green spaces will benefit local residents and visitors and also be home to a diversity of plant and animal species. The projetct's integrated planning and design will create synergies that generate more value from every dollar invested for climate mitigation, adaptation, public health and other ecnomic benefits. Below are illustrations of project location and concepts. The project also integrates landscaping and tree-planting in public spaces and along roads as medians, bioswales, applying the sponge city principles of increased planting areas, more space for tree-roots and infiltration enablers.

The project applies an advanced method of ecological river rehabilitation integrated with soil bioengineering to all project rivers. This innovative method of instream river training allows improvement of rivers naturally and it allows their ecological condition under both dry weather and low water flow level conditions as well as for river flood protection during flood events. The principle of this method of instream river training is to work with rocks and boulders that are carefully placed on the riverbed below the water line. This creates local turbulences which lead to riverbed alterations, slower and faster flows within the river stream, and temperature differentials which increase habitat and biodiversity of fish and other plant and animal species. During a heavy rainstorm event, the instream river training method will lead to a physical build up and acceleration of water masses through such hydrodynamics. This in turn will reduce need for river embankment enforcement and allows soft and green river edges with enhanced ecology and biodiversity.

The project contributes to and complements domestic activities. Changzhi City was the only city selected as part of 20 demonstration cities for the new national sponge city program to systematically promote sponge city planning and construction. The key tasks in this action plan include ecological restoration and governance projects, flood prevention and drainage construction projects, water environment governance projects, water resource utilization projects, urban renewal and transformation projects, industrial base construction and control, and strengthening sponge city capacity building.

Planning support included land use planning for a higher density mixed use urban core area based on transit and walking. ADB proposed a central green space and a pattern of small blocks and streets. Investments include roads with bus lanes and bus stops, proper sidewalks and bicycle lanes, green medians and trees and a major central green space between the rail station and the airport. A green network for hydraulic functions and public open spaces. Blue arrows show principle of cool air pathways as ventilation corridors from the mountain to the Zhangzi lake and along the project green spaces.

For another subproject area a network of streets with greenways and green connections and pocket parks all designed with sponge city functions were proposed by ADB, as well as on-site sponge city measures for buildings. Reuse of treatet wastewater is also supported as part of water security and circular economy concept. Source: Nengshi Zheng, Zuo Heping, Du Yipeng and Stefan Rau for Asian Development Bank, based on Google Earth.

Qinyuan County Subproject and Proposed Blue-Green Network Masterplan. Project investment components are marked in red lines or outlines with ecological river rehabilitation and flood risk management and greenway development as green capital investments, and as solid dark red line for the road. These projects will contribute to a functional blue-green network that provides multiple ecosystem services benefits including flood risk reduction and urban cooling improving climate resilience and they also serve as amenities for people and sink carbon emissions. The road will provide a bypass for the county seat and complete a public transport and bicycle and pedestrian network. Source: Nengshi Zheng, Design Institute based on google earth for Asian Development Bank.

5 STRENGTHENED INSTITUTIONS ENGAGE WITH PRIVATE SECTOR AND PEOPLE

The worsening climate challenge and increasing numbers of disasters mandate transformational change quicker and beyond what may have been anticipated previously. Relevant, swift, deep, and ubiquitous change of the way we are used to think about and do things is imperative to mitigate and adapt to the changing climate, but also to decisively act to stop and reverse ecological, biodiversity, and pollution challenges. This requires changes in many areas and institutions and in the way public and private stakeholders, communities and individuals communicate and collaborate. And it needs changes in the way engineers are trained and contractors work. In other words a lot of system inertia needs to be overcome.

Reform government institutions and integrate sponge city with comprehensive risk management. Creating sponge cities by using NbS, like other climate adaptation and mitigation actions, will be effective only if all

concerned administrative sectors and all government levels are coordinating. They should engage businesses and communities for resilience and resource and land-use efficiency. All risk mapping, climate adaptation and mitigation planning, and operational work in a city should be coordinated at a high level and the sponge city goal needs to be treated as an important part of the overall strategies of a city. It is also important to integrate disaster risk management (both as physical and non-physical interventions) into spatial planning, investment prioritization and operations, as well as climate risk insurance. The Sendai Framework for Disaster Risk Reduction provides guidance on reducing natural or manmade disaster risks through an integrated and inclusive, multihazard, multilevel, and cross-sector approach to reduce loss of lives, assets, and economic damage.

Governance improved to enable cross-sector and cross-risdictional coordination for resilience with low-carbon urban transformatioon to optimize co-benefits. Multilevel and cross-sector governance mechanisms need to be improved to: ensure that open space and ecosystems are protected, and for the planning of new urban areas integrate flood and drought resilience planning – while also integrating low-carbon urban form principles. Adapt existing urban areas to introduce NbS with green spaces that are optimized for both resilience and to reduce greenhouse gas emissions. Urban land use and form should be based on compact city concepts with recreational green spaces that increase resilience while also serving as recreational areas, reducing the need for travel to find respite for residents. These and more aspects are under the responsibility of different agencies and private sector contributors and effective coordination is critical for the success of sponge city.

Governance improved to enable integrated cross-sector and cross-risdictional green-blue and gray infrastructure applied systemically and systematically. It is critical to cover entire urban areas to contribute to comprehensive climate resilience. Well-planned and protected blue (i.e., surface water) and green open spaces in a city and urban region have the capacity to reduce flood risk while also improving the local management of rainwater and urban heat risks. Cities will also become greener and more livable. Most effective in reducing flood risk is the integration of green and gray infrastructure into a comprehensive system that works together and across rural and urban areas, combining water conveyance, retention, detention, and infiltration. Drainage pipes, channels, deep tunnel and storage facilities, walls, and dykes can be most effectively linked with green roofs, rainwater harvesting, rain gardens, sunken parks and sport fields, bioswales, wetlands, and protected floodplains. As urban areas im many cases go beyond local jurisictions it is important to enable mechanisms for cross-jurisdictional coordination, through higher government mandates or voluntary cooperation.

Integrate flood and drought risk management on river-basin level. Comprehensive operational integration of managing natural resources, water, land use, infrastructure, and climate resilience and disaster risk on a river-basin level across local administrative boundaries should be prioritized and be part of formalized governance and planning coordination (S.P. Groff and S. Rau, 2019).

Revise education curricula, engineering handbooks and standards. Academic institutions should include NbS, bio-engineering and biomimicry in civil and environmental engineering curricula. Professionals, universities, thinktanks and concerned national ministries should build a broad knowledge base and show evidence from best practice cases. Cost–benefit analysis of projects and programs should include NbS options and quantified benefits to help overcome acceptance and inertia challenges.

Engage public and private sectors, new partnerships with communities, and land- and asset-owners. It is important to also engage early on and with a broader section of the population is important. People of all ages and walks of life should be educated on the risks of climate change to promote low-carbon lifestyles. Thinktanks, academic institutions, and professionals should promote study tours to best practice NbS and sponge cities to make tangible the benefits of these blue-green systems. Engage with children in kindergartens, schools and adults at universities and other education facilities. It is essential to engage with communities, households, individuals, and private companies as they are the occupants of land parcels that should be made green to provide local stormwater retention functions, contributing to overall urban resilience. This can happen through awareness raising and capacity building as well as market-based instruments like incentives and disincentives and access to finance for blue-green system investments. Investments in green infrastructure can also be made through public–private partnerships.

Mobilize sustainable finance, public finance priorities and leverage private funds. Urban climate change adaptation and the sponge city approach deserves a continued high level of priority and adequate resource allocation. Doing nothing will be both costly and fatal, based on climate-related disasters in recent years. It is imperative to secure adequate funding and government attention to ensure people and cities are resilient and safe. This applies to retrofitting existing urban areas with risk-mapping and risk-informed planning of new areas.

6 APPLICATION OF SPONGE CITY OUTSIDE THE PRC

The sponge city concept existed both in the PRC and elsewhere before the term was coined for example as low-impact design, water-sensitive design, integrated rainwater management, among others. It is being applied with this same name in many places outside of the PRC i.e. in Asia, Europe, the Americas and Oceania. The city of Copenhagen in Denmark has been a pioneer. Some cities in Germany like Berlin and Hamburg have developed complrehensive implementation plans and even established specific agencies and continue to implement retrofitting and new-development pilots (Berlin Regenwasseragentur, 2019; Hamburger Stadtentwässerung, 2015). The United States' Environmental Protection Agency published a seminal technical guide for local governments and private stakeholders and home owners to inspire green infrastructure and NbS (United States EPA, 2015). Vienna in Austria, Zurich in Switzerland and many other cities around the world adopt the concept (Stadt Wien, 2023). The proof of the sponge city concept stimulates other ciites around the world to apply the principle, like for example Berlin and Hamburg in Germany.

The principles and design elements are more or less the same or similar adjusted for local conditions and space availability, while the mechanism of planning, public communication and consultation are adapted to the local conditions and cultures. Retrofitting existing urban areas is challenging everywhere in the world, also in the PRC. And for new urban areas it is challenging with many stakeholders and land owners for integrating sponge city planinng as part of risk-informed planning. The PRC's practice of establishing sponge city offices directly reporting to the Mayor allows them to cooperate across agencies for planning and implementation of projects and building systems. The cases of Hamburg and Berlin where the local public water companies drive the sponge city initiatives and have also established separate agencies to prepare comprehensive city-wide drainage plans and promote the concept demonstrates that it can be successfully implemented outside of the PRC. The Berlin and Hamburg governments' authority to mandate local rainwater interception, retention and/or infiltration and educating and promoting local incremental projects to decouple territories from the gray drainage systems are impresive cases for the concept's relevance for building urban water and -heat related resilience successfully. Of course these two cases are examples only and there are many others, at various stages of planning and implementation.

7 CONCLUSIONS

Rapidly increasing urbanization together with climate change-related hazards from increased frequency and severity of extreme weather events require urgent urban adaptation. Nature-based solutions (NbS) can enhance climate resilience, effectively reducing disaster risks including floods, droughts, urban heat islands, desertification, and landslides.

The Sponge City program in the People's Republic of China (PRC) supports water-related NbS and green infrastructure, such as wetlands, water retention parks, rain gardens, bioswales, pervious pavement, and green roofs, to improve water management and reduce urban runoff and flooding, urban cooling, better air, carbon sequestration and improved air quality while delivering many other ecosystem benefits for livability and urban competitiveness. People enjoy green spaces and the diversity of flowers and birds and are willing to pay for improvements. Cities enjoy higher tax incomes from increased land value.

NbS and sponge cities should be mainstreamed, deepened, and combined and systemically integrated with improved gray infrastructure like optimized drainage pipe networks. To do this requires refotm and transformation and overcoming significant policy, institutional and industry inertia. Strides are needed in policies that prioritize adaptation; technical support for analysis; risk-informed planning to retrofit urban areas; and the prioritization of functional green space planning. It also requires education to overcome reservations towards, and inertia of of engineering and contracting industry to enable rapid acceotance and uptake of sponge city and NbS.

The concept is proven, however, when applied holistically as a territorial principle of decentralization and decoupling from technical drainage systems. The main challenge is to apply this widely retrofitting urban areas with the realities of existing paving and structures and the need to engage stakeholders and owners. Communities, private sector and individuals. Scare public financial resources need to be spent effectiveley and efficiently and private resource leveraging is essential to build urban resilience. Priority is to be given to those measures that are well designed and deliver many benefits, i.e. NbS for low-carbon and resilient development for resource use effectiveness and efficiency. That is multiplying benefits from the investments.

The popularity of the concept reached well beyond the PRC. Through engaging stakeholders and communities it can also be applied in differenent institutional contexts, also for the much needed retrofitting of urban areas, sites and buildings. And the concept should be mainstreamed as key contribution to urban climate resilience and biodiversity enhancement as local and even global public good. The beauty of the concept is the effectiveness and efficiency of NbS with multiple co-benefits from the scarce resources invested. And the increasing engagement of private sector and real estate owners, i.e. in Berlin and Hamburg, and also in the PRC is most encouraging and urgently needed for effectiveness of resilience across urban regions.

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Conceptualising Smart Cities in the Japanese Planning Culture

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1 ABSTRACT

Smart cities have been a field of action in spatial development for quite some time. Building on the societal trend toward digitalization, the nexus of digitalization and spatial development has been planned and researched since the turn of the millennium (Hollands 2008). In the highly competitive segment of smart cities, platform solutions from large IT and consulting companies are often applied (Hollands 2015). In addition, an international discourse emerged in research that critically reflects on the smart city concept itself (Grossi and Pianezzi 2017). Today, all over the world many cities are applying smart solutions, and position themselves as smart cities, but how are smart cities conceptualized in different planning cultures?

The Japanese planning culture is charcterized by strong centralization with the central government being the main actor in development (Pallagst et al. 2018; Martinez-Fernandez et al. 2016). In addition, the Japanese society is highly challenged by demographic change and ageing. Consequently, the aspect of ageing plays a role in all Japanese policies, also in the context of smart cities (interview with staff at the German Instiute for Japanese Studies, Tokyo, July 2023). Yet how are smart cities conceptualized in the Japanese planning culture, what are the main drivers and goals, who are the main actors, and which policies are at hand? And – given the societal context of demographic change and ageing in Japan – how is the aspect of ageing taken into consideration in the concept of smart cites in Japan?

This paper will shed light on conceptualizing smart cities in the Japanese planning culture. Starting with a brief introduction to the concept of planning cultures with a special emphasis on Japan, it will present two cases of smart cities in Japan, trying to answer the questons outlined above.

The research presented here is part of the project ‘Ageing Smart’ carried out by a consortium at RPTU Kaiserslautern-Landau funded by the Carl-Zeiss-Foundation. This particular part of the project aims at scrutinizing the application of smart cities in different planning cultures, among others Japan – discussing their potentials and detecting possible best practice examples.

Keywords: Japan, planning, culture, givernance, smart cities

2 SMART CITIES AND PLANNING CULTURES

Spatial planning systems are based upon different institutional and cultural conditions. While these may present comparable features, these planning systems were designed to operate in distinct cultural, normative and spatial situations (Pallagst 2010). Meanwhile, a considerable discourse on planning cultures has emerged with a range of defintions about what planning cultures could comprise (Knieling and Othengrafen 2009; Levin-Keitel and Othengrafen 2017; Sanyal 2005). Pallagst et al. (2021) suggested an operative definition of planning culture as follows: “Planning cultures encompass the societal aspirations towards planning – its processes and its outcomes. It refers to the values and shared beliefs of stakeholders involved in planning, and the methods and tools they are applying and producing. Planning cultures are not static but constantly evolving in line with societal changes or planning related challenges. Planning cultures as we see it can be attached to specific territorial entities, be it nations, sub-nations, regions, or cities − most likely but not necessarily within administrative boundaries. In addition, they can be attributed to cities or regions having to face specific planning problems”.

In order to expand empirical research on topical planning cultures, Pauly and Pallagst (2023) proposed investigating possible changes in planning cultures in conjunction with digitalization. In order to derive a typology of planning cultures applicable for a variety of planning contexts, the authors modified Othengrafen’s culturized planning model (Othengrafen 2010). This model offfers layers of planning culture such as “societal context”, “planning context”, and “planning toolset”.

The author's previous research made clear that planning cultures can be investigated by evidence based research utilizing for example shrinking cities, or border areas. In general, spatial planning offers many subjects which might offer windows of investigation for planning cultures. Research by Sorensen (2015) suggests that planning cultures might change when faced with "critical junctures of institutional change and innovation in planning systems" (Sorensen 2015). One of these critical junctures might be the context of digitalization. In order to conceptualize planning cultures and digitalization, the authors suggested a research frame involving digitalization in the facets and layers of planning culture (Pauly and Pallagst 2023).

The research on changing planning cultures in view of digitalization is a novel field, and – since digitalization is a very broad arena – it can be attributed to several factors of digitalization. One of them could be smart cities. The authors suggest that the use of digital tools such as AI, visualizations and platform solutions poses new requirements for spatial planing in terms of conceptualizations, decision-making and participation processes. This, in turn, has consequences for the planning tools and the competencies of spatial planners and other actors in the planning and development process. In general, implementing smart cities already might have initiated changes in planning cultures, which is one of the main hypotheses of this paper.

When looking at the Japanese planning culture the planning system is highly centralized with a focus on economic development and market orientation (Martinez-Fernandez et al. 2016; Mallach et al. 2017; Sorensen 2011). Plans, programs and policies are developed on national level, and the implementation appears to be strictly top down. Plans and policies are implemented on regional and local level with only basic adaptation towards the specific location. Although planning documents on national level refer to regional or local best practice examples, the selection of those cases seems not transparent since there is no system of developing those best practices within defined parameters (Interview with Norio Miki, Nomura Research Institute, 2018).

Moreover the Japanese planning culture is challenged by several societal transitions. In particular preparing for disasters and for demographic change and the path towards an ageing society have longstanding impact on policy-making in Japan (interview with staff members from the German Insitute for Japanese Studies, Tokyo, 2023). Population data by the United Nations, Department of Economic and Social Affairs, Population Division (2024) shows that ageing is a force the Japanese society needs to account for since many years and for the years to come. For this reason, the planning cultural context needs to involve societal aspects such as the aspect of ageing.

The following paragraphs will shed light on the smart city context of Japan with some emphasis on the specific requirements of an ageing society, and the potential implications on the Japanese planning culture.

3 SETTING THE SCENE FOR SMART CITIES ON NATIONAL LEVEL: SOCIETY 5.0

The "Science and Technology Basic Plan", which is updated every five years (MEXT n.d.), resembles the basic framework and vision for the future technological development of the Japanese economy and society, and therefore also for the cities. The fifth edition of this plan, presented by the Japanese government in January 2016, refers to various IT initiatives in China, the USA and Germany (Germany: "Industry 4.0") and can also be seen as a response to these. The Japanese concept from 2016 goes deeper than the transformation of the economy and, against the backdrop of a rapidly ageing society, presents the vision of a "super-smart society", a "Society 5.0" (Waldenberger 2018).

Society 5.0 describes the desired future form of society, based on the "merging of cyberspace and physical space" (Hitachi-UTokyo Laboratory 2018), following the 'hunter-gatherer', 'agrarian', 'industrial' and "informational society". The city structure is also changing from a 'network city' in the current "informational society" to an 'autonomous decentralized city' in Society 5.0 (Hitachi-UTokyo Laboratory 2018). The "Comprehensive Strategy on Science, Technology and Innovation" (STI) prioritizes the initiatives listed in the Science and Technology Basic Plan on an annual basis (Cabinet office 2017). The 2017 update characterizes Society 5.0 as the "vision of future society (...) [that] will be a human-centered society that, through the high degree of merging between cyberspace and physical space, will be able to balance economic advancement with the resolution of social problems by providing goods and services that granularly address manifold latent needs regardless of locale, age, sex, or language to ensure that all citizens can lead high-quality, lives full of comfort and vitality." (Cabinet Office 2017: (STI) for 2017, as cited from: Hitachi-UTokyo Laboratory 2018)

The central motif of Society 5.0, the merging between cyberspace and physical space, means in terms of implementation the comprehensive collection of data, the merging and processing of this data by AI in integrated systems and the use of the data by public or private end user applications (Deguchi et al. 2018). Among all the problems to be addressed by Society 5.0, the demographic change in Japanese society, which is causing a declining workforce and thus also declining productivity, is given a special significance (Audrey, Kusuma Paksi 2022). Society 5.0's fields of action include among other the extension of the healthy lifespan, realization of the mobility revolution, etc. In these areas, technologies already known from Society 4.0, e.g. the Internet of Things (IoT) or artificial intelligence (AI), are to be used to create the conditions for maximizing productivity, for example through fewer sick days or a later retirement age due to better health. The inclusive approaches of the Society 5.0 concept, on the other hand, aim to increasingly integrate groups into the workforce, who are not yet fully available to the labor market, such as women (Fukuyama, Mayumi 2018).

Society 5.0 aims to transform not only the industry (see "Industry 4.0 in Germany") or cities, but society itself, with the necessary structural and technical changes to "merge the cyberspace and the physical space" taking place in people's living environment. An existing concept that has already been implemented in some cities to link new technologies with the built environment is the 'smart city'. The smart city approach in Japan over the past two decades has had a clear focus on the introduction of new technologies, particularly in the energy sector (Deguchi 2028). Based on the challenges that cities are already facing, such as an ageing society, far-reaching requirements for the design of a smart city can be derived from Society 5.0. Key points that must play a greater role in smart city concepts in the future according to Society 5.0 include the human-centered approach and the solution of social problems as well as sensor-based data collection and the increased use of the Internet of Things (Deguchi 2018). As concrete approaches for implementation of technology, the Cabinet Office's "Smart City Guidebook" cites real-time data collection for disaster prevention, the cashless society, autonomous transportation and logistics, and improving health through the use of ICT (Information and Communications Technologies) (Cabinet Office 2021). On the other hand, strengthening bottom-up initiatives with 'citizen-based technology' in smart city projects is seen as a way to implement the abstract goal of a 'human-centered society' with a focus on solving social problems (Deguchi 2018).

Two approaches for implementing smart city projects have established themselves so far: the 'government-initiated type' at city level and the 'area management type' at neighborhood level, whereby in the past the initiative in many cases came from public authorities (Cabinet Office 2021).

Smart city initiatives of the government initiated type are concerned with the entire city or larger sub-areas. The focus lies on the performance and efficiency of the administration, as well as improving the provision of various public services. The process is usually organized by a committee led by the city (Cabinet Office 2021), with close cooperation between the public and private sectors often playing an important role despite public leadership (Deguchi 2018). The main tasks of the city include the development of the objectives and strategy, the organization of the committees and working groups as well as the administration of the entire process (Cabinet Office 2021). So far, good results have been achieved when the smart city project was embedded in city-wide (integrated) strategy and planning, including the participation of residents and stakeholders (Deguchi 2018).

On the other hand, there is the area management type, which relates to a specific neighborhood with its specific problems and challenges. As the initiative in this case often comes from the neighborhood itself, smart city projects usually aim to improve the quality of life of residents and strengthen local businesses. The process is organized in a neighborhood management/development council consisting of public and private stakeholders. Similar to the government initiated type, the task of the city government is to initiate, set up and support this council, however in contrast, the local private actors are mostly involved in drawing up the strategy (Cabinet Office 2021). Finally, the concluded measures are implemented in close cooperation with local stakeholders such as businesses and residents, often in the form of a public-private partnership (Deguchi 2018).

The following two chapters take a closer look at one example each of a smart city of the government initiated and the area management type.

4 TWO EXAMPLES OF SMART CITIES IN JAPAN

4.1 A management initiated smart city initiative: OMY-district

4.1.1 Background

The districts of Otemachi, Marunouchi and Yurakucho (OMY-district) are located between the grounds of the Imperial Palace (Edo castle) and the Tokyo station built in 1914 (Tokyo Omy Council n.d.a). Large parts of the site were originally used by the army and were sold to the first president of the Mitsubishi Company in 1890 (Mitsubishi Estate 2022). In the following decades, the area was developed into Japan's first office district and due to its numerous red brick buildings it was given the nickname ‘London Block’. The remaining state-owned areas were privatized in 1955 (Tokyo OMY Council n.d.a). In the subsequent economic boom, the area was ‘remodeled’ and a modern office district was created (Mitsubishi Estate 2022).

At the height of the “bubble economy” of the 1980s, the property owners of the OMY districts organized themselves with the founding of the ‘OMY District Redevelopment Project Council’, later renamed the “Council for Area Development and Management of Otemachi, Marunouchi, and Yurakucho” (here: “the council”) (Tokyo OMY Council n.d.b). This first merger came about against the backdrop of an overheated real estate market, increasing competition between the districts of Tokyo and major plans by real estate companies such as the “Marunouchi Redevelopment Plan”, later also referred to as the “Manhattan Plan” (Dimmer 2012). When this bubble burst, the ambitious real estate development plans were put on hold and a reorientation took place. The aim was now to revitalize the existing stock, so that the focus shifted to attracting foreign companies and developing a high-quality working environment, particularly in view of various demographic trends and the expected shortage of staff. It was also intended to shake off the image of an old, monofunctional office district (Dimmer 2012). In 1995, the governor of the Tokyo Metropolitan Government drew up a plan to revitalize the city center, which focused, among others, on the street between the station and the Imperial Palace in the heart of the OMY district (Dimmer 2012). At the same time, the “OMY Advisory Committee” was founded in 1996. Its members include the Tokyo metropolitan government, the Chiyoda ward, the East Japan Railway Company and the Council for Area Development and Management of Otemachi, Marunouchi, and Yurakucho (Tokyo OMY Council n.d.c). The overarching goal of this committee is to discuss the future development of the district between the public planning authorities and the property owners. The result of this public-private partnership is the “Guideline for the Redevelopment of the Area” (here: “the guideline”) published in 2000, in which key development goals were laid down, such as the appearance of the skyline (Dimmer 2012). This guideline is regularly updated, most recently in 2021 (Tokyo OMY Council n.d.b) and continues to set groundbreaking goals for the development of the district. The non-profit organization ‘OMY Area Management Association’, founded in 2002, also integrates the tenants of the commercial properties and the community into the urban development process. The tasks of this NPO consist of “integrated management” of the public space and the implementation of projects for the community (Dimmer 2012).

Since the 2010s, the response to increased global competition between cities as a result of globalization became increasingly important. This led to the need to create attractive and vibrant neighborhoods to attract foreign companies (The Real Estate Companies Association of Japan 2022). The Smart City Vision based on the guidelines and jointly formulated by the council, the city of Tokyo and the Chiyoda district in 2019 should be viewed against this backdrop.

4.1.2 Organization

The OMY-district emerged as the first office block in the history of Japan (Tokyo OMY Council n.d.a) and is still an important commercial area centrally located between Tokyo Station and the Imperial Palace. As the largest property owner, owning 33% of the land in the OMY district (Mitsubishi Estate Co., LTD. n.d.), the Mitsubishi Estate company is a major player in the development of the district. The first remodeling plan was drawn up by Mitsubishi back in 1959, and today the company plays a leading role in the Council for Area Development and Management of Otemachi, Marunouchi, and Yurakucho and thus continues to have a major influence on the development of the district (Mitsubishi Estate 2022).

As already mentioned, the council represents the property owners of the OMY district and can be regarded as the central body for project-orientated neighborhood development. Full members are therefore exclusively companies based in the OMY district; the Chiyoda ward and various public agencies are listed as supporting

members (Tokyo OMY Council n.d.d). The council has set itself the goal of promoting growth through urban planning, particularly in public spaces, and sees its tasks in the implementation of neighborhood development projects. The objectives and projects are coordinated with local stakeholders and public authorities through the regularly updated Guidelines for the Redevelopment of the Area (Tokyo OMY Council n.d.e). The projects are ultimately developed in committees, including the 'Committee for Smart City Planning and Promotion', whereby the Mitsubishi Estate Company, as a major player, provides the chairperson or deputy chairperson in almost all of the committees (ibid.). The council is supplemented by the Eccozeria in the field of social projects and sustainability, the Area Management Association, which is primarily concerned with the community and the management of public space, as well as various other organizations (Tokyo OMY Council n.d.c).

The council therefore performs important urban planning tasks at district level and drives development forward in a project-oriented manner. However, the public planning authorities of the Chiyoda district and the Tokyo Metropolitan Government do have an influence on the development of the neighborhood. For this purpose, the OMY Advisory Committee, a public-private partnership between the council, the Tokyo Metropolitan Government, Chiyoda ward and the East Japan Railway Company (ibid.), was founded. Through the work of this committee, the project-oriented planning at neighborhood level can be embedded in the overarching urban development planning.

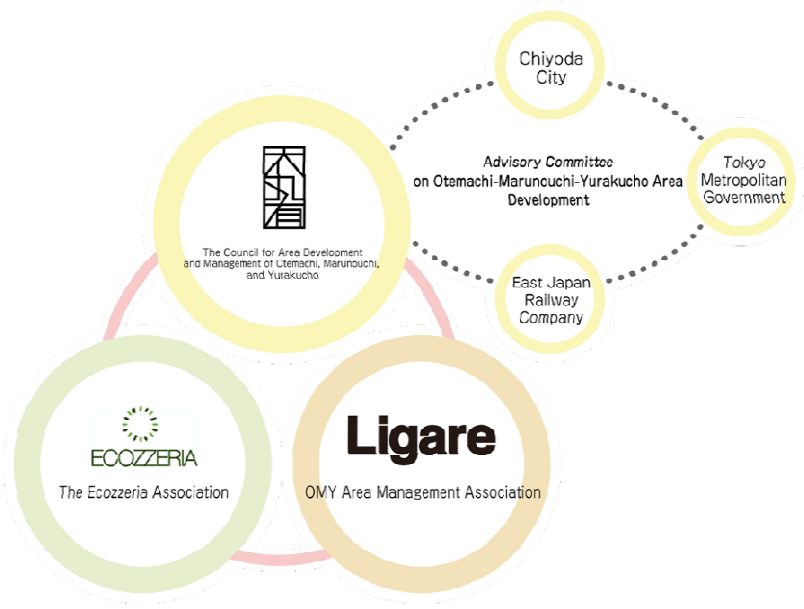

Fig. 1: OMY Public-Private Partnership (Tokyo OMY Council n.d.c)

4.1.3 Smart city approach

As mentioned at the beginning, profiling as a modern and attractive place to work became increasingly important in the urban development of the 2010s and also found its way into the guidelines. Under the motto "Smart and Walkable", development goals such as "Cultural area, that attracts and bustles with people" or "Convenient, comfortable area, that people can walk around" (Tokyo OMY Council n.d.f) bear witness to this new orientation. With the goal "Smart area, that utilizes cutting-edge technologies and data" (ibid.), the guideline sets the course for smart city projects and shows that the smart city has the potential to achieve the ambitious development goals.

Cooperation between the state institutions and private organizations in the OMY district as a public-private partnership in the form of area management is considered crucial for the implementation of the objectives, including the smart city (ibid.). The cooperation between public and private actors, organized in the "OMY Area Smart City Promotion Consortium", mainly relates to public relations and the coordination of the smart city project with the ideas of politics and administration. At the center, however, is the Committee for Smart City Planning and Promotion based at the council, which is also the contact address for the numerous collaborations. In addition to the aforementioned cooperation with public authorities, there is also contact with universities, the Ministry of Land, Infrastructure, Transport and Tourism and, above all, organizations operating at a city-wide level (Tokyo OMY Council n.d.g). Another partner is the Tokyo Marunouchi

Innovation Platform, a network of government, academia, various companies of the OMY-district and the local community in form of the council etc., aiming to connect the businesses and to support the demonstrations of (smart city) projects in the area (TMIP n.d.).

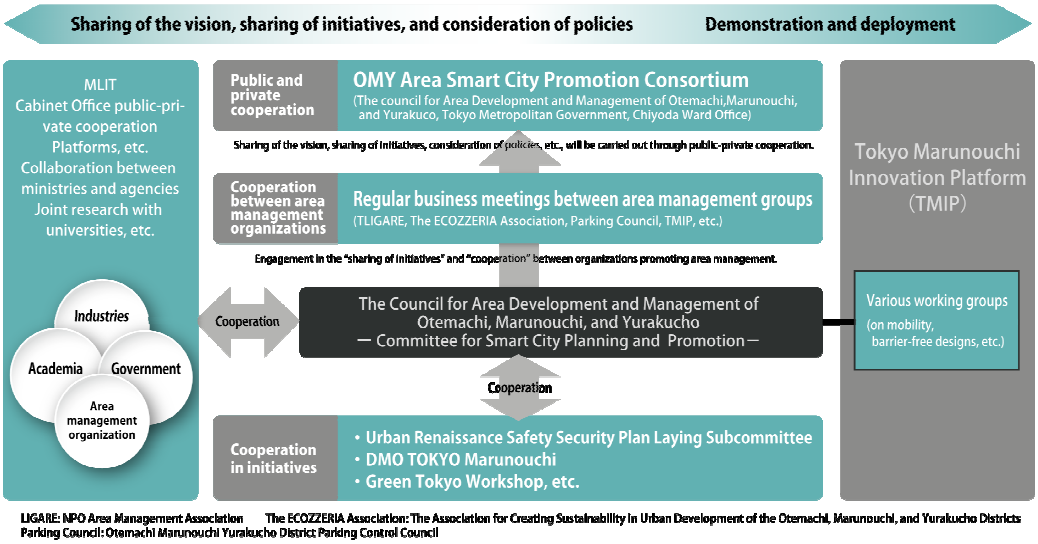

Fig. 2: Organizaltional chart of the OMY smart city initiative (The Council for Area Development and Management of Otemachi, Marunouchi, and Yurakucho n.d.)

The objectives for neighbourhood development are coordinated with the city and the district through the guidelines and therefore also define the objectives and framework conditions for the smart city. In relation to national initiatives it should be mentioned, that the smart city concept is not derived directly from Society 5.0, but rather stands alongside it. Therefore the implementation of these concepts is primarily aimed at increasing the attractiveness of the district for workers and increasing resilience to disasters and diseases (Advisory Committee 2023). In the 2023 update of the guidelines, the idea of the smart city is further elaborated. The cross-sectoral orientation, the importance of public-private cooperation and implementation by the area management are emphasized here. However, the focus of the guidelines is on the introduction of new technology such as AI, IoT and extensive data collection and usage. For the citizens and workers, the smart city can be experienced through new data and digital services and the renewal of public space. In the spirit of Society 5.0, the aim is also to change people's values and behavior (Advisory Committee 2023).

The system

The design of the data and IT system is based on the goal of creating a data-based area management model. To do this, the available data, generated by apps or sensors for example, is first brought together on a data utilization platform and entered into a digital twin, a 2D or 3D version of the OMY-district. Various applications can now access this collected and processed data. Services for area management, such as a dashboard for visualizing the data or various simulations for district development, can access the data directly, while applications for individuals and companies, as well as the public, have access to open data through the 'Data Library' (OMY Area Smart City Promotion Consortium 2020).

In the area of private applications, the Oh My Map! app, which provides information on mobility, events, etc. in the neighborhood can already be used. As a public application, the Area Management City Index is also already being used as a tool for visualizing area management activities and the beta version of the OMY dashboard presents relevant information and serves as a data basis for area management (Tokyo OMY Council n.d.h).

Another important project is the redesign of public spaces according to the motto "Smart and Walkable", based on the "Mobility as a Service" concept, which also introduces new forms of mobility such as self-driving buses. In order to increase the attractiveness of the area, there is an increased focus on concentrating transport infrastructure in mobility hubs and creating walkable streets with flexible use (OMY Area Smart City Promotion Consortium 2020).

4.1.4 Discussion

Due to several factors, the smart city initiative in the OMY-district is unique and resembles an "extreme form" of the area management types discussed in the Society 5.0 chapter. With the Mitsubishi Estate company the area has a dominant, professional owner, which holds a large part of the land and has been managing it since the end of the 19th century. The smart city initiative was also launched from this position to respond to existing problems, aiming to make the area competitive as an office district for the coming decades and to secure and increase the value of the properties and the profits generated. Against the backdrop of a changing and increasingly diverse workforce, revitalizing and increasing the attractiveness of the district, in the sense of transforming it from a monofunctional office district into a vibrant working district with a high quality of life, is seen as the best way to achieve these goals. The smart city concept in OMY is designed accordingly and places great emphasis on visualizing the plans and the milestones already achieved as well as on creating a new image and promoting the initiative.

These structures are also evident in the organization of the initiative. The framework and objectives were developed in a public-private partnership (OMY Area Smart City Promotion Consortium), so that the ideas on urban development of the Chiyoda district and the Metropolitan Tokyo Government are considered in the design of the smart city. However, the Council for Area Development and Management of Otemachi, Marunouchi, and Yurakucho and thus the owners of the OMY district are responsible for the development and implementation of the individual projects. A clear division of tasks between public and private actors is therefore evident. It should be noted that public-private partnerships and joint urban development in the district were already established with the founding of the OMY Advisory Committee in 1996. To be able to finance the smart city initiative in the long term, public and private players plan for a joint funding. Therefore, the added value generated by the smart city, e.g. the increased tax revenue or the increased turnover and profit of the companies, should be reinvested in the smart city and thus ensure sustainable financing based on growth (OMY Area Smart City Promotion Consortium 2020).

However, the OMY smart city initiative is not geared towards society or the city as a whole but has a clear focus and a limited user group and as a result, many important aspects of the smart city such as housing, schools, etc., are not addressed. What significant effects and advantages the smart city initiative actually has for the city or the district and its specific user group, in addition to the advertising aspect, remains to be seen as the implementation of the vision and projects progresses.

Due to the special circumstances, findings are only transferable to a limited extent, especially because only the working age group is considered in the OMY smart city initiative. However, the case study shows very well the potential of public-private partnerships and area management, as well as the importance of local stakeholders for urban development. In addition, individual projects, and above all their implementation within the framework of area management, show possible applications of ICT technologies in urban areas. The new mobility concepts and the redesign of the public space aim at increasing the attractiveness of the district for workers in the OMY district but are just as relevant for other groups such as the ageing resident population in other districts.

4.2 A government initiated smart city initiative: Smart City Takamatsu

4.2.1 Background

For its future, the city of Takamatsu sees the declining birthrate, the super-aging society and the transformation of the economy, with far-reaching consequences for the city and its population, as the determining trends and challenges for urban development. The implementation of a smart city concept as a part of sustainable urban development is seen as an opportunity to respond to these challenges by increasing the attractiveness of the city, improving administrative efficiency, and maintaining citizen services. The potential of the smart city is seen above all in the use of ICT technologies and services (Takamatsu City General Affairs Bureau Information Policy Division ICT Promotion Office 2019). In addition to these social challenges, the focus of Takamatsu's smart city vision is on disaster management. In 2004, a typhoon caused massive damage in the city, and since then great efforts have been made to protect the population from natural disasters. This topic area was therefore also placed at the center of the concept in the city's smart city vision (Mochizuki et al. 2020).

The process was also initiated by the “Declaration to Create the World's Most Advanced Digital Nation” published by the Japanese government and the associated “Basic Plan for Promoting Public and Private Sector Data Utilization”, which encourages municipalities to digitize and provide data. For this purpose, the “ICT Promotion Office” within the Information Policy Division of the General Affairs Bureau was established in 2017 (Takamatsu City General Affairs Bureau Information Policy Division ICT Promotion Office 2019). In addition, the smart city Vision serves the implementation of Society 5.0, with the goal "to create a digital government that promotes collaboration" (Takamatsu City General Affairs Bureau Information Policy Division ICT Promotion Office 2019).

4.2.2 Organization

Also in 2017, the Smart-City Takamatsu Promotion Council (here: “the council”) was founded as the central organization for the creation and implementation of the smart city vision. The main task of the council is the promotion of a common data platform in order to solve issues through cooperation of the industry, the government, academia and the community (Cabinet Office 2022). In this function, it is also seen as a platform for an open exchange of ideas and innovation. To this end, the council enjoys extensive autonomy, although it was initiated by the city, is chaired by the mayor and the city administration takes on administrative tasks. The original 14 members of the council, government agencies, companies and NPOs, are organized in the general assembly as the decision-making body with a supervisory function (Oga/Kobayashi 2018). The Steering Committee is subordinate to the general assembly and is made up of elected representatives of the general assembly. It is responsible for defining key topics, setting up working groups for these topics and processing the results of the working groups to present them to the general assembly. The establishment of one of the aforementioned working groups can be proposed by all members of the council on specific topics (JASCA n.d.a). The council is supported by external experts and the ICT Promotion Office, which takes on administrative tasks such as the publication of the Smart City Takamatsu Promotion Plan and serves as a secretariat for the council (Cabinet Office 2022).

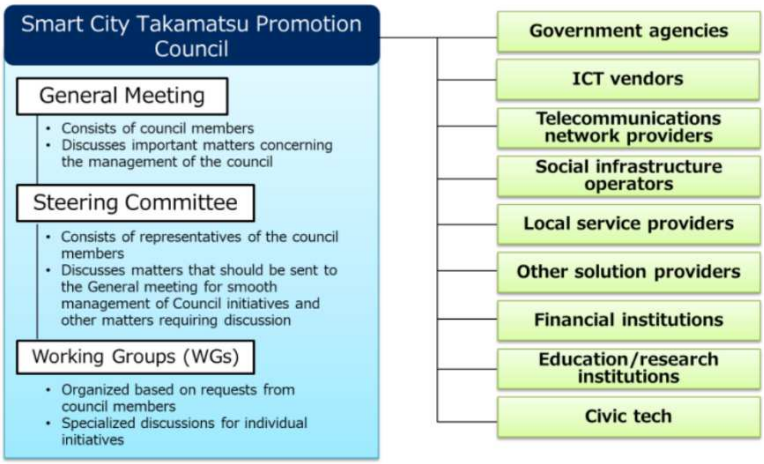

Fig. 3: Organizational chart of the Takamatsu smart city initiative (JASCA n.d.a)

However, the council's function is not only to work on the vision and concepts, it also serves in particular as an idea multiplier, by establishing contacts and exchanging ideas between the members. The communication of the smart city vision and the exchange between the individual members and the local community, as well as participation and public relations work, are also essential for the work of the council (Oga/Kobayashi 2018).

4.2.3 Smart City approach

Behind the vision of a smart city, presented in the Smart City Takamatsu Promotion Plan, and other urban development projects in Takamatsu, is the desire to counter the current trends such as declining population, declining birthrate, and super-aging society and to achieve sustainable growth despite these prospects. The utilization of ICT and data as well as a firm collaboration of various entities is seen as the key to achieve this vision. The main areas of application are seen as reforming and digitizing administration, creating new civic services, and increasing their efficiency, particularly in light of the rising demands of the population and increasing complexity in planning. By considering the 6th Takamatsu City Comprehensive Plan, the Smart

City Takamatsu Promotion Plan was integrated into cross-sectoral urban development planning (Takamatsu City General Affairs Bureau Information Policy Division ICT Promotion Office 2019).

The Common IoT platform

The Smart City Takamatsu Promotion Plan calls in particular for the increased use of ICT and the digitalization of administration. As part of disaster management, one of the first projects was the creation of a common IoT platform, which can be used to collect, process, and visualize sensor data (Mochizuki et al. 2020). Up to this point, for example, water levels in the harbor etc. were regularly measured by hand and the data was then entered into the system (Mochizuki et al. 2019). As one of the first projects to be implemented, the common IoT platform is at the heart of the smart city. However, the platform can and will also be used for a range of other applications (Ishii, Atsushi 2018). The platform is based on technology from Fiware, a product of the EU's Future Internet Public-Private Partnership (fi-ppp) program, with the aim of supporting municipalities in setting up smart city initiatives. Fiware is already widely used in Europe, but Takamatsu is the first Japanese city to implement this technology (ibid.).

All of the required data is supplied by sensors, for example for recording water levels in the port and rivers, cameras for recording traffic and pedestrian flows, or provided by external sources such as weather data. As this data is available in different formats, it is first collected on the server and then converted into a unified and standardized format so that the various applications can access it. Once the data has been converted, the common IoT platform provided by Fiware is responsible for the management, processing, and deployment of the data. Finally, the processed data is shared with the applications via Application Programming Interface API (Mochizuki et al. 2020). A distinction is made between public applications such as the dashboard for visualizing data for the city and the public (Takamatsu City Dashboard and Citizen Dashboard) and applications provided by third-party providers (JASCA n.d.b.). The public applications can access and process all available data, for the applications offered by third parties, even if they serve the provision of public services, a demonstrative environment for the common IoT platform has been created. Through this separate platform, partners from industry and academia, government agencies and the community will be able to freely access the data provided and create new projects and applications for the city and the community (Takamatsu City n.d.). This platform was initially tested with open data and information on traffic safety, such as accidents (JASCA n.d.b.). However, further use in the areas of disaster prevention, tourism, welfare, and transportation is planned (Takamatsu City n.d.).

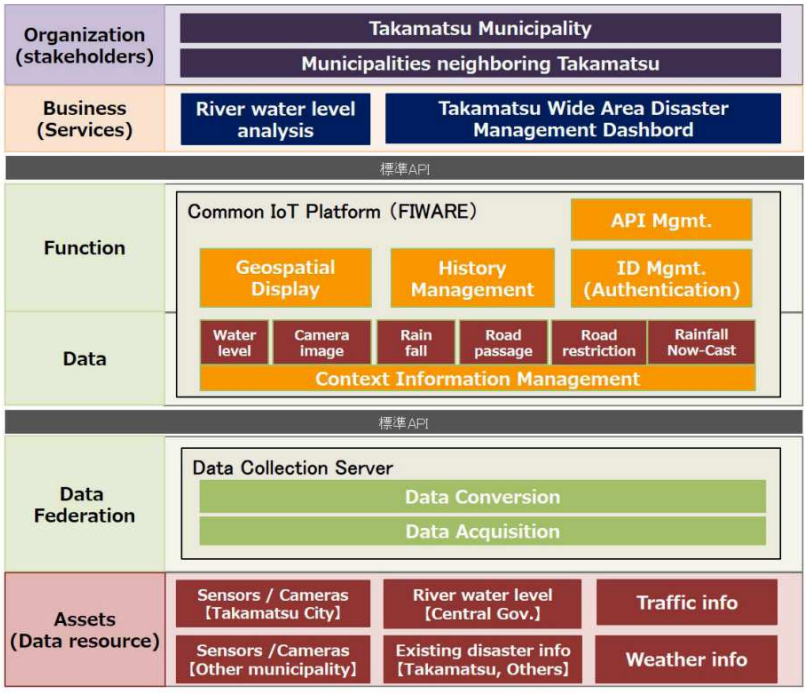

Figure 4 - System Architecture of Wide-Area Disaster Management Service

Fig. 4: Functional scheme of the common IoT platform (Mochizuki et al. 2020)

The platform is particularly relevant in the area of disaster management, as the real-time recording of water levels and the combination of this data, including the Japan Meteorological Agency's rainfall forecast, which

is updated every 5 minutes, has greatly improved the city's ability to provide early warnings. In addition to the collection of data concerning the water levels, recorded by sensors and surveillance cameras installed in the city, data on traffic and the capacity of shelters is collected as well. The data collected and processed by the common IoT platform can now be accessed by Takamatsu's administration via the 'Takamatsu wide area disaster management dashboard' and used to make quick decisions based on this real-time information and, above all, on up-to-date and precise data. Concrete examples of application include early warning, efficient traffic management depending on the trafficability of the roads and the distribution of the population to the shelters. In addition to these aspects of safety, there is also the possibility of saving on personnel, which will become increasingly important in the coming years due to demographic change (Mochizuki et al. 2020). In addition, the information can be made available to the population via the "My Safety Map" so that Takamatsu residents can take a direct route to safety (JASCA n.d.b.). The Smart City Takamatsu Promotion Plan particularly emphasizes the importance of cooperation. A good example of the implementation of this cooperation is the initiative for wide area disaster resilience launched in 2020, in which the City of Takamatsu joined forces with Kan'onji City and Ayagawa Town to better respond to wide-area disaster events such as typhoons or floods (Mochizuki et al. 2020).

However, other services are already being offered and tested via the platform as well. One example is the spatial analysis of traffic accident data and the timely warning of drivers of dangerous or accident-prone sections of the road network. Another application is the provision and advertising of rental bikes in the city, as it has been established that user behavior differs depending on the country of origin of the tourists. The "Watch over Elderly" programme though, which aims to monitor the elderly through wearable devices, for example to detect falls and reduce the response time of the ambulance, will be of the greatest importance in the coming years (Mochizuki et al. 2020). Drawing on this pioneering project, there is still a lot of potential in this area, by building a monitoring system to offer elderly people in particular a better quality of life and prevent loneliness (Takamatsu City General Affairs Bureau Information Policy Division ICT Promotion Office 2019).

In the area of cooperation and the implementation of Takamatsu Smart City Vision projects, the "Town Data Laboratory" is a particularly interesting example. In this project, the citizens of Takamatsu and Kagawa Prefecture can program their own prototypes of applications based on the common IoT platform and test and evaluate those of the other participants. To implement the project, the city of Takamatsu, which provides the data and interface to the common IoT platform, is cooperating with Kagawa University and the Information and Communication Exchange Center "eTopia-Kagawa". In addition to gaining new ideas for applications and their design, the university's aims at promoting local talent whereas eTopia-Kagawa's is given the task of improving the ICT literacy of the citizens of the prefecture. By providing a "set of programming libraries and sample applications (called prototyping support tools)" (Cabinet Office 2022), the barriers to participation are kept as low as possible so that, in principle, all citizens who have some experience with Microsoft Word, including schoolchildren, for example, can contribute their ideas. One example for an idea that emerged from the project is the publication of data from the city cleaning service on the quantity, location and time of collected leaves, so that cleaning work can be better coordinated with street festivals and costs can be saved (Cabinet Office 2022).

4.2.4 Discussion

With the establishment of the Smart City Vision Takamatsu, the city is attempting to respond to significant social trends, such as the ageing of society, with a comprehensive strategy by ensuring to maintain the overall attractiveness of the city and boosting the efficiency of the administration in terms of the provision of civic services through the increased use of ICT technology. However, in the early phase of the smart city initiative, the focus is on solving specific issues through independent projects, such as improving disaster management. To implement the vision, the city has set up the Smart City Takamatsu Promotion Council, in which it is involved as an equal member. This gives the city a dual function in the promotion of the smart-city vision. On the one hand it supports networking between industry, academia and government and strengthens public-private cooperation concerning the smart city vision, by establishing and participating in the council. On the other hand, the city provides the council with certain guidelines, including the Comprehensive Plan, for coordination with the city's overall development and is the driving force behind the implementation of most projects. This means that the city is primarily responsible for financing projects,

especially the common IoT platform. It also provides financial support to small and medium-sized enterprises, which are often interested in participating but do not always have the necessary resources to go digital (Takamatsu City 2021). In addition, many other projects are already being implemented or at least tested, but in some cases, there are difficulties due to financing and economic viability, for example with the wearable devices in the Watch over Elderly project (Takamatsu City 2021).

Whether the smart city initiative can actually bring about comprehensive changes beyond individual applications and make a significant contribution to solving the problems arising from demographic trends will only become apparent as the number of successfully implemented projects increases. In the area of project-oriented application of ICT technologies in the city, however, Takamatsu plays a pioneering role and can be seen as a field of experimentation. Findings from the watch over elderly program, for example, should be taken into account when setting up smart city initiatives in other cities. Furthermore, planning for the elderly is a cross-sectional task, meaning that the elderly as a vulnerable population group that places special demands on the design of the city, need to be given special consideration in the smart city initiatives and the projects that implement it, such as in the disaster management via the common IoT platform.

5 CONCLUSIONS

Smart cities in the Japanese context is driven by broad societal transformations and it showcases symptoms of a planning culture which operates by a hierachical mode in a top-down planning system. But, as broadly as smart cities is applied as a concept in Japan, it is also relevant to ask, if it has the potential to initiate change in the Japanese planning culture. This chapter demonstrated that the aspect of ‘smart’ has a large impact on the Japanese society through the policy area Society 5.0, setting the framework for large societal changes. This policy operates in a hierarchical mode. But also the two cases of the OMY-district and of the smart city Takamatsu represent the strong role of the government both in planning and in smart cities.

We also observed that smart cities are facilitating existing and new networks of stakeholders in planning such as public-private-partnerships, and/or neighborhood groups. Smart cities also target specific societal problems such as disaster preparedness and ageing. In terms of the challenge of Japan being an ageing society, we learned that smart cities is facilitating elderly people by specific policies and smart solutions, but smart cities is also utilized in order to make cities more attractive for younger people – most likely with the goal to attract new people or to keep younger people from moving out.

For that, the smart city provides planners with new tools like, above all, the extensive collection and subsequent merging and visualization of data in order to make better and faster decisions, save costs in administration and maintain or improve the range of civic services. In general, smart cities might make planning processes in Japan more transparent and facilitate the governance of planning processes. Yet it seems to operate within the existing planning culture and it also seems to contribute to sustaining it.

At the same time, however, the two examples described with partial very ambitious goals, also raise a number of questions that have yet to be investigated further. For example, it is not clear how the mechanisms for making work processes more efficient will actually succeed in the various use cases and thus solve socio-demographic challenges. At a technical level, too, the question often arises as to where already well-known technologies contain a new innovative approach through the smart city initiatives

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🏆 *reviewed paper*

Cruising in KL: Lokalisierung und Quantifizierung von Parksuchverkehr mittels Floating Car Data

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1 ABSTRACT

Cruising oder auch Parksuchverkehr bezeichnet den Verkehr, der entsteht, wenn Autofahrende einen verfügbaren Parkplatz im öffentlichen oder bewirtschafteten Straßenraum suchen, der ihren Erwartungen entspricht und dabei nicht (vollständig) über die Orte freier Parkstände informiert sind. Hierbei können Gebühren oder die Nähe zum Zielort eine Rolle spielen (vgl. Hagen et al.). Es bezieht sich demnach auf jene Abschnitte der Strecke, die durch ein Kraftfahrzeug zurückgelegt werden und über die unmittelbare Wegverbindung hinausgehen. Dieser Verkehr bedingt, abhängig von der Antriebsart, Emissionen von Schadstoffen und Lärm sowie unabhängig von der Antriebsart, eine zusätzliche Beanspruchung des Straßennetzes. Es gibt Schätzungen, dass Cruising in bereits untersuchten amerikanischen Städten bei 5-6% aller Fahrten vorkommt und weniger als 1% des Verkehrsaufkommens ausmacht (vgl. Weinberger et al.). Andere Quellen gehen jedoch häufig pauschal von bis zu 30% des Gesamtverkehrs aus (vgl. Barter).

In Kaiserslautern sollen diese Werte unter Nutzung von Floating Car Data(FCD) validiert konkretisiert werden: in welchen kleinräumigen Gebieten tritt anteilig wie viel Parksuchverkehr auf? Wo suchen Autofahrende vermehrt nach freien Parkständen und wo legen sie dafür die größten zusätzlichen Strecken zurück?

Die für diese Untersuchung verfügbaren Floating Car Daten wurden im Herbst 2022 durch Smartphone-Apps erhoben, die sich mit dem Kraftfahrzeug verbinden und in kurzen zeitlichen Intervallen von maximal 15 Sekunden folgende Merkmale erfassen: Position, Zeitpunkt, Fahrtrichtung und Geschwindigkeit. Ihre Durchdringung des gesamten Verkehrs beträgt gemäß den Angaben des Datenbereitstellers etwa 5-10%. Mittels eines Algorithmus werdenFahrten, die mit Cruising enden, identifiziert und anschließend quantifiziert unter besonderer Berücksichtigung der Unsicherheiten, die bei der Erfassung und Verarbeitung der Daten entstehen, wie bspw. unbeabsichtigt erfasste Fußwege.

Diese Arbeit widmet sichzunächst der Bewertung der Qualität der verfügbaren Daten und ihrer Eignung für Analysen des Parksuchverkehrs. Es werden Möglichkeiten aufgezeigt, auf Unsicherheiten hingewiesen und wesentliche Hinweise für die Vorgehensweise bei der (Vor-)verarbeitung gegeben.

Die Ergebnisse dieser und zukünftig aufbauender Auswertungen können Personen, die für Parkraumbewirtschaftung und Verkehrssteuerung verantwortliche sind, dabei unterstützen nachhaltige und fundierte Entscheidungen zu treffen. Darüber hinaus kann die Menge an Parksuchverkehr ein Indikator für die Lebensqualität in kleinräumigen Gebieten sein, da sie unmittelbar die Lärmbelastung, Luft- und Aufenthaltsqualität beeinflusst (vgl. Agora).

Keywords: mobility, cruising, Parksuchverkehr, floating car data, Kfz

2 MOTIVATION

Die Lebensqualität von Menschen an ihren jeweiligen Wohnstandorten wird von einer Vielzahl an Faktoren beeinflusst. Diese reichen von der Wohnsituation selbst, einschließlich Wohnungsgröße und Bezahlbarkeit, über soziale Verbundenheit bis hin zu verschiedenen Umweltfaktoren.Zu letzteren gehören insbesondere auch die Luftqualität und Lärmbelastung, die durch das lokale Verkehrsauskommen maßgeblich beeinflusst werden.Jenes wirkt sich darüber hinaus auch auf das Sicherheitsempfinden der Bewohneri:nnen aus und beeinflusst somit auf mehrere Ebenen deren empfundene Lebensqualität(vgl. Bundesregierung).

Genäß einer umfassenden Datenanalyse des Spiegel verzeichneten deutsche Metropolen und Autobahnen seit 2019 einen Rückgang des Verkehrsaufkommens um fünf bis 14 Prozent (vgl. Dambeck). Verkehrsplanerinnen und Verkehrsplaner setzen gezielte Maßnahmen wie Geschwindigkeitsreduktion und

Stärkung von ÖPNV, Rad- und Fußverkehr ein, um vor allem den motorisierten Individualverkehr zu reduzieren, im Bestreben, die Klimaschutzziele im Verkehrssektor zu erreichen (vgl. Umweltbundesamt).

Abwendbarer Verkehr ist die Suche nach einem geeigneten Parkplatz, da dies zusätzliche Strecken und somit auch vermeidbare Emmissionen, Lärm und eine Belastung der Infrastruktur verursacht. Dieser als Parksuchverkehr oder Cruising[1] bekannte Verkehr entsteht, wenn Autofahrende einen passenden Parkstand im öffentlichen oder bewirtschafteten Straßenraum suchen, ohne (vollständige) Informationen über verfügbare Parkmöglichkeiten zu besitzen. Hierbei können Gebühren oder die Nähe zum Zielort, aber auch höchst individuelle Ressourcen eine Rolle spielen (vgl. Hagen et al.).

Die Autodichte, gemessen als Anzahl privater Autos pro Einwohner, ist in den letzten Jahren kontinuierlich angestiegen (vgl. Zeit Online), was voraussichtlich auch den Bedarf an Parkflächen erhöht. Die Auslastung vorhandener Parkplätze steigt, und es entsteht ein sogenannter Parkdruck. Die häufige Parkplatzsuche kann die Lebensqualität der Anwohnerinnen und Anwohner also gleichermaßen negativ beeinflussen wie das Cruising anderer Verkehrsteilnehmer in ihrem Wohngebiet.

Die Herausforderung der Quantifizierung des Parksuchverkehrs beschäftigt Stadtplanerinnen und Stadtplaner seit den 1970er-Jahren. Die herkömmliche Methode der Verkehrszählungen an Knotenpunkten hat jedoch ihre Mängel, da sie auf die Zuverlässigkeit der Zählenden angewiesen ist und nur punktuelle Daten erfasst. Alternativ können Umfragen in der Bevölkerung genutzt werden, bieten jedoch kein umfassendes und neutrales Bild.

Neue Techniken wie fest installierte Sensorsysteme zur Verkehrserfassung bieten Kommunen neue Möglichkeiten detaillierte Echtzeitinformationen über die Verkehrsauslastung an festen Orten zu gewinnen.Bewegungsdaten von Kraftfahrzeugen(Kfz)geben einen tieferen Einblick in den Verkehrsfluss und das Fahrverhalten, da sie sowohl eine Auswertung einzelner Fahrten als auch aggregierte Auswertungen für bestimmte Gebiete und Zeiträume ermöglichen.

Im Folgenden wird beschrieben wie Floating Car Data (FCD) in und um die Stadt Kaiserslautern genutzt wurden, um Orte zu identifizieren, an denen Fahrten enden, die durch einen Algorithmus als Parksuchverkehr kategorisiert wurden. Diese Informationen können Verkehrsplanerinnen nud Verkehrsplanern Aufschluss über das Fahrverhalten, einzelner, den Parkdruck in verschiedenen kleinräumigen Gebieten Kaiserslauterns und Anregungen für mögliche weiteren relevanten Untersuchungen liefern.

3 PROJEKTKONTEXT

Die Untersuchung, die im Rahmen einer Bachelorarbeit durchgeführt wurde, ist aus dem durch die Carl-Zeiss-Stiftung geförderten Verbundprojekt „Ageing Smart – Räume intelligent gestalten“ entstanden. Im Fokus des Gesamtprojektes stehen die Babyboomer, also die geburtenstarken Jahrgänge von 1955 bis 1969, durch deren Eintritt in das Rentenalter Kommunen vor Herausforderungen gestellt werden. So sind diese oftmals damit konfrontiert, neben altersgerechten Wohnstandorten auch passende Versorgungs- und Freizeitstrukturen zu schaffen. Das Gesamtprojekt hat sich als Ziel gesetzt, ein datengestütztes Entscheidungsunterstützungssystem (Decision Support System) zu entwickeln, das Mitarbeitenden der öffentlichen Verwaltungen in ebendiesen Planungsprozessen unterstützt. Insgesamt zehn Teilprojekte aus den Fachbereichen Raum- und Umweltplanung, Informatik und Mathematik der RPTU am Standort Kaiserslautern bearbeiten interdisziplinär diese Fragestellung.Ebenso involviert ist das Fraunhofer-Institut für Experimentelles Software Engineering (IESE) sowie das Deutsche Forschungszentrum für Künstliche Intelligenz (DFKI) GmbH.

Um präzise Kenntnisse über die Verkehrsauslastung an unterschiedlichen Wochentagen und zu verschiedenen Tageszeiträumen in den kleinräumigen Gebieten der sieben Modellkommunen zu gewinnen, hat das Konsortium Bewegungsdaten erworben, die sukzessive ausgewertet werden.

Kaiserslautern ist eine dieser ausgewählten Modellkommunen, die seit 2020 im Rahmen des Projekts "Modellprojekte Smart Cities" (MPSC) durch das Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen (BMWSB) gefördert wird. In enger Kooperation mit dem SmartCity Living Lab (SCLL) des

[1] Die Wörter Cruising und Cruisen haben sowohl im deutschen als auch im englischen neueren umgangsprachlichen Sprachgebrauch andere Bedeutungen als in diesem wissenschaftlichen Kontext.

Deutschen Forschungszentrums für Künstliche Intelligenz (DFKI) wird unter anderem das Projekt "Smart City Infrastructure" realsiert, bei dem Sensoren zur Verkehrsmessung sowie zur Erfassung der Lärmbelastung und Luftqualität installiert wurden.

Von der Stadt Kaiserslautern wurden im Rahmen des Möbilitätsplans Klima+ 2030, der 2018vom Stadtrat verabschiedet wurde, verschiedene Maßnahmen zur Reduzierung des motorisierten Verkehrs im Stadtgebiet beschlossen und teilweise bereits umgesetzt. Diese umfassen eine Prakraumbewirtschaftung, Carsharing-Angebote, Park und Ride Parkplätze und die Schaffung von Fahrradstraßen(vgl. Huber-Erler et al.).

4 DATENGRUNDLAGE UND -VORVERARBEITUNG

Die Ergebnisse dieser Arbeit beruhen fast ausschließlich auf den im Rahmen des Forschungsprojekts erworbenen Floating Car Data. Lediglich im Explorationsprozess wurden anekdotisch Bilder aus Straßenbefahrungen der Stadt Kaierslautern hinzugezogen, um feststellen zu können, wie die Parksituation am Ende eines Pfades real aussieht (vgl Abb.1). Alle Kartendarstellungen und Auswertungen wurden mit Openstreetmap (OSM) Daten vollzogen.

4.1 Floating Car Data (FCD)

Bei den verwendeten Floating Car Data handelt es sich um von[ui!] - the urban institute erworbenen Daten, die von Smartphone-Apps erfasst werden, welche sich mit dem benutzten Kfz verbinden. Es bleibt unklar, um welche Art von App es sich handelt. Die angegebene Durchdringung liegt bei 5-10%. Das heißt, es sind5-10% des Gesamtverkehrs erfasst worden.

Bei der Nutzung der App werden einzelne Datenpunkte im Abstand von maximal 15 Sekundengespeichert, die eine ID enthalten, um eine Zusammensetzung der Datenpunkte zu zusammenhängenden Pfaden zu ermöglichen. Desweiteren wird die Geschwindigkeit zum jeweiligen Zeitpunkt und die Position, angegeben in Längen- und Breitengrad. Weiterhin werden ein Zeitstempel und die Fahrtrichtung gespeichert.

Attribut	**Beispiel**	**Bemerkungen**
ID	1161716616	Zufälligvergeben
Geschwindigkeit in km/h	15	
Zeitstempel	2022-11-05T01:00:19.000Z	Genauigkeit:Millisekunden
Längengrad	7.76199	WSG 84
Breitengrad	49.4409	WSG 84
Fahrtrichtung in Grad	125	Ausgehendvomgeographischen Norden

Tabelle 1: Attribute der genutzten FCD mit einem beliebigen Beispiel.

Betrachtet wurden zunächst die FCD von einem einzigen Tag: Samstag, dem 5.11.2022 in einem rechteckigen Gebiet um die Stadt Kaiserslautern mit einer Größe von ca. 839 km2. Für diesen Bereich und diesen Zeitraum liegen 1,413,102 Datenpunkte vor, die zunächst zu Pfaden zusammengesetzt werden müssen.

Da die Smartphone-App oft nach Beenden der Fahrt weiterläuft, werden auch Fußwege erfasst, die im Anschluss an die Fahrt getätigt werden. Diese müssen in einem Vorberarbeitungsprozess unter Tätigung von bestimmten Annahmen „abgeschnitten“ werden (siehe Abschnitt 4.2).

Das Attribut der Fahrtrichtung wird in diesem Ansatz nicht genutzt, kann aber potenziell zusätzliche Informationen liefern und einer Verfeinerung des Algorithmus dienen.

4.1.1 Anmerkungen zur Datenqualität

Die Angaben des Datenbereitstellers zur Durchdringung lassen sich ohne Weiteres nicht überprüfen. Desweiterenist es wahrscheinlich, dass durch die Art der Erfassung eine Verzerrung zustande kommt, da bestimmte Altersgruppen eher seltener Smartphone-Apps nutzen. Da es unklar ist, um welche Art von App es sich handelt, ist auch unklar, ob eine Verzerrung bzgl. Einkommensstruktur vorliegt, da bspw. nur neuere Kfz über die Möglichkeit eine Kopplung mit dem Smartphone bieten. Darüber hinaus ist offen, ob und welche Auswirkungen solche Verzerrungen auf eine Auswertung haben können. Vermutlich haben Menschen aus höheren Einkommensgruppen öfter einen privaten Stellplatz und leisten sich eher

kostenpflichtige Parkplätzeim Zentrum. Weiterhin kann man keine Aussage darüber treffen, ob bestimmte Gewerbe wie Taxi-Unternehmen oder Lieferdienste übermäßig starkvetreten sind.

Da sich die IDs in unbekannten zeitlichen Abständen und unter unbekannten Voraussetzungen ändert, lassen sich mit diesen Daten generell keine Aussagen über ein langfristiges oder wiederholtes Parksuchverhalten eines einzelnen Kfz machen.

Beim Vorverarbeiten der Daten gab es einige Auffälligkeiten, die bei der Bewertung der Ergebnisse berücksichtigt werden müssen (siehe Abschnitt 4.2.2.).

4.1.2 Anmerkungen zum Datenschutz

Die Bewegungsdaten liegen in anonymisierter Form vor und enthalten keine personenbezogenen Informationen. Sie werden trotzdem als schützenswert eingestuft, da man aus ihnen unter bestimmten Umständen unter Zuhilfenahme zusätzlicher Informationen herauslesen könnte, wohin eine Person an einem bestimmten Tag gefahren ist. Dies kann nur geschehen, falls man weiß, dass eine Person einen privaten Parkplatz besitzt, wo sich dieser befindet, die Fahrt tatsächlich dort startete oder endete und sie zu den 5-10% gehört, deren GPS-Daten erfasst werden.

Fahrten, die auf öffentlichem Grund beginnen und enden, lassen keine Rückschlüsse auf einzelne Personen zu. Da in diesem Anwendungsfall lediglich die letzten Datenpunkte eines Trips genutzt werden und es zunächst keine Rolle spielt, wo die Fahrt startet, kann man diesen Fall vernachlässigen.

Man kann davon ausgehen, dass Parksuchverkehr entweder auf einem Parkplatz im öffentlichbewirtschafteten Prakstand endet oder, falls die Person nicht fündig wird, in einem privatbewirtschafteten Parkraum.

Trotzdem werden alle Pfade, die in dieser Arbeit visualisiert und veröffentlicht werden, darauf geprüft, ob sie auf einem privaten Grundstück enden bzw. Auswertungen in aggregierter Form dargestellt, bei der keinerlei Rückschlüsse auf einzelne Fahrten mehr möglich sind.

4.2 Preprocessing der FCD

Um die Daten sinnvoll nutzen zu können, waren zunächst folgende Schritte notwendig:

(1) Minimierung der Datenmenge

Um eine besser zu verarbeitende Datenmenge zu erhalten, wurde zunächst alle Punkte in einem Radius von 100m, um die Bundesautobahnen A63 und A6 entfernt. Da ein großer Anteil der gesamten Datenpunkte auf diesen Bereich fallen, er jedoch für Parksuchverkehr irrelevant ist, wurde dieser Schritt ergriffen, um eine schnellere und einfachere Handhabung zu errreichen.

(2) Abschneiden von Fußwegen

In diesem Anwendungsfall ist es unbedingt notwendig, Fußwege abzuschneiden, die nach Beendigung oder zwischen zwei Fahrtenungewollterweiseaufgezeichnet werden, wenn die Smartphone-App weiterläuft und weiter Bewegungsdaten erfasst. Um Fußwege nicht fälschlicherweise als Parksuchverkehr zu identifizieren, wurden sukzessive5 Minuten-Fenster betrachtet. Wenn die drei Punkte am Beginn dieser Fenster alle eine Geschwindigkeit kleiner als 7km/h haben und das gesamte Fesnter eine Durchschnitttsgeschwindigkeit kleiner als 7 km/h, wurden die Datenpunkte im Fenster entfernt.

(3) Erstellung von Trips

Einzelne Datenpunkte können durch Nutzung ihrer ID und ihres Zeitstempels in zusammenhängende Pfade zusammengesetzt werden. Hierbei wurde davon ausgegangen, dass zwei verschiedene Fahrten vorliegen, wenn mehr als 5 Minuten zwischen den zwei zeitlich nächsten Datenpunkten liegen bzw. mehr als 5 Minuten die Geschwindigkeit 0 ist.

Auf diese Weise kommt man bei diesem Datensatz auf insgesamt 9.808 Pfade, die auch Trips genannt werden.

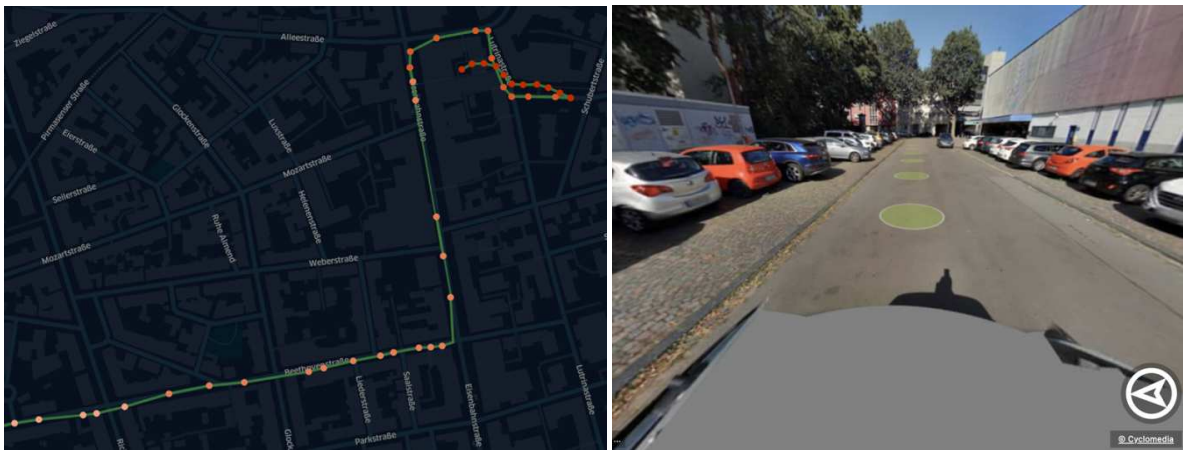

Abb. 1: Ein Trip mit aufgezeichnetem Fußweg am Ende (links),visualisiert mit kepler.gl. Das Kfz wurde im Bereich auf dem rechten Bild (Screenshot Streetsmart) geparkt und dann zu Fuß die letzte Strecke (rote Punkte)zurückgelegt.

4.2.1 Keine Nutzung von Map-Matching-Algorithmen

Durch unpräzise Erfassung der GPS-Korrdinaten kann es vorkommen, dass Datenpunkte neben der Straße liegen und durch das Zusammensetzen der Trips Ecken „abgeschnitten“ werden (siehe Abb. 2). Diese Fehler in den Rohdaten kann man durch so genannte Map-Matching-Algorithmen korrigieren. Diese bergen jedoch die Gefahr von Verzerrungen oder Ungenauigkeiten an anderer Stelle. Es wurde hier also bewusst auf eine Anwendung von Map-Matching verzichtet.

Wenn man nämlich davon ausgeht, dass folgende Annahmen zutreffen, wird die Detektion von Parksuchverkehr nicht beeinflusst:

- Der zu detektierende Parksuchverkehr findet im Stadtraum statt.
- Die dort zugelassene Höchstgeschwindigkeit von max. 50 km/h wird nicht überschritten.
- Datenpunkte haben einen maximalen zeitlichen Abstand von 15 Sekunden.

Folglich kann ein Kfz zwischen zwei Datenpunkten maximal 208m zurücklegen. Bei einer rechtwinkligen Kreuzung würde man nach Pythagoras im schlechtesten Fall 61m zu wenig berücksichtigen. Dies entspricht einem möglichen Fehler von weniger als 42% und hat somit keine Auswirkung auf die Berechnungen des Algorithmus (vgl. Abschnitt 5). Insbesondere ist zu beachten, dass es sich hier um eine maximale Fehlerabschätzung handelt. In der Realität, fahren Kfz mit geringeren Geschwindigkeiten um Ecken und viele Strecken bestehen auch aus geraden Abschnitten, bei denen der Fehler im Allgemeinen viel geringer ausfällt.

Abb. 2: Die Fehler, die durch unpräzise GPS-Koordinaten oder die direkte Verbindung zweier zeitlich aufeinanderfolgender Datenpunkte ohne Berücksichtigung der Straßenführung entstehen, können in diesem Anwendungsfall vernachlässigt werden.

5 VERWENDETE TECHNOLOGIEN

DieDaten wurden ausschließlich in frei verfügbarer Software verarbeitet:

- Die Datenvorverarbeitung wurde in Pythonunter Nutzung derBibliotheken geopandas undgeopyausgeführt.
- Für Visualisierungen wurde kepler.gl genutzt. Dies ist eine leistungsstarke Webanwendung für die visuelle Analyse von (großen) Geodaten.Es eignet sich auch für sensitive oder proprietäre Daten, da diese und deren Auswertungen ausschließlich auf dem eigenen Browser/Rechner bleiben und nicht an deren Server gesendet werden
- Zur Berechnung der Distanzen zwischen den einzelnen Datenpunktes eines Pfades und derkürzesteenDistanzenwurde das Python-PaketOSMnxgenutzt, das auf den OpenstreetMap Daten operiert.

6 METHODIK

Zur algorithmischen Identifikation von Parksuchverkehr sind Indikatoren nötig, um ihn vom regulären Verkehr eindeutig unterscheiden zu können. Wir orientieren uns hierbei an den Ansätzen von Weinberger et al., die sich am Vergleich der zurückgelegten Streckenlänge mit der kürzest möglichen Strecke in einem 400m-Radius um den Zielpunkt der Fahrt orientieren.

6.1 Definition von Parksuchverkehr

In der wissenschaftlichen Literatur existiert keine einheitliche Definition derBegriffe Parksuchverkehr oder Cruising, die eine algorithmische Unterscheidung vom anderen Verkehr zulässt. Es ist offen, ob der Parksuchverkehr erst beim Erreichen des Zielortes oder bereits früher (in einem so genannten Akzeptanzgebiet) beginnt. Jenes Gebiet sei von vielen Faktoren wie etwa Tageszeit und Ortskenntnis abhängig und zudem sehr individuell. Andere Autorinnen und Autoren nähern sich über das Fahrverhalten an und betrachten Geschwindigkeit und wiederholte Abbiegevorgänge (vgl. Wegener).

Offensichtlich istjedoch die Tatsache, dass bei Parksuchverkehr eine größere Strecke zurückgelegt wird als in dem Fall, wenn der optimale Parkplatz direkt verfügbar ist. Diese vermeintlich simple Tatsache kann als technische Grundlage einer algorithmischen Identifikation ausreichen.

Es werden nun folgende verfügbare Informationen eines gewählten Pfadesoder eigens definierte Größen genutzt, um Parksuchverkehr zu identifizieren:

x	letzter Punkt eines Pfades (Ort des gewählten Parkplatzes)
r	Größe des Radius um x in Metern
y	(zeitlich) erster Punkt des Pfades innerhalb eines Kreises um xmit Radius r
dist_min$_{x,y}$	kürzeste Strecke zwischen den Punkten x und y, berechnet mit OSMnx
dist_real$_{x,y}$	Länge des entlang des Pfades von x nach y
excess_ratio	= dist_real$_{x,y}$ / dist_min$_{x,y}$ Überschussverhältnis
k_{min}	Unterer Schwellenwert
k_{max}	Oberer Schwellenwert

Definiere demnach für eine algorithmische Suche: Für feste k , r >1 und einen gegebenen Pfad liegt dann **Parksuchverkehr** vor, wenn k_{min}>excess_ratio> k_{max}.

Weinberger et al. betrachten einen Radius von r = 400m um den Endpunkt der Fahrt und berechnen die kürzeste Strecke zwischen dem Zielpunkt und dem (zeitlich) ersten Punkt des Pfades innerhalb dieses Radius. Diese wird dann mit der tatsächlich gefahrenen Strecke zwischen diesen beiden Punkten verglichen.

Falls die tatsächlich gefahrene Strecke mehr als k_{min} = 1,5-fach länger als die kürzest mögliche Verkehrsstrecke ist, wird davon ausgegangen, dass es sich um Parksuchverkehr handelt.

Abb. 3: Ein Beispiel von detektiertem Parksuchverkehrinnerhalb eines 400m-Radius um den Parkplatz (rot). Die kürzeste Strecke beträgt hier 542m, die tatsächlich gefahrene mehr als 1047m.

6.2 Anmerkungen zu Excess Ratio und Ausreißer

Da die Fehlerabschätzung für die Ungenauigkeiten der GPS-Messungen und das fehlende Map-Matching einen Wert f = 1,41 ergeben, sollte $k_{min} > f$ gewählt werden. In der Betrachtung der Excess-Ratios fiel auf, dass manche Fahrten extrem hohe Überschussverhältnisse aufweisen.

Bei Fahrten mit excess_ratio > 5 = k_{max} wurde davon ausgegangen, dass ein Fehler oder Ausreißer vorliegt und es wurden jene Pfade ausgeklammert (147 Pfade von 361). Es fiel bei einer genaueren Betrachtung auf, dass solche hohen Überschussverhältnisse dann auftreten, wenn der Pfad wiederholt in den Umkreis mit gegebenem Radius ein und austritt. Dies kann insbesondere bei Taxifahrten oder Lieferdiensten der Fall sein, da die Fahrerinnen und Fahrer oft wieder an ihren Ausgangsort zurückkehren (vgl. Abb. 4).

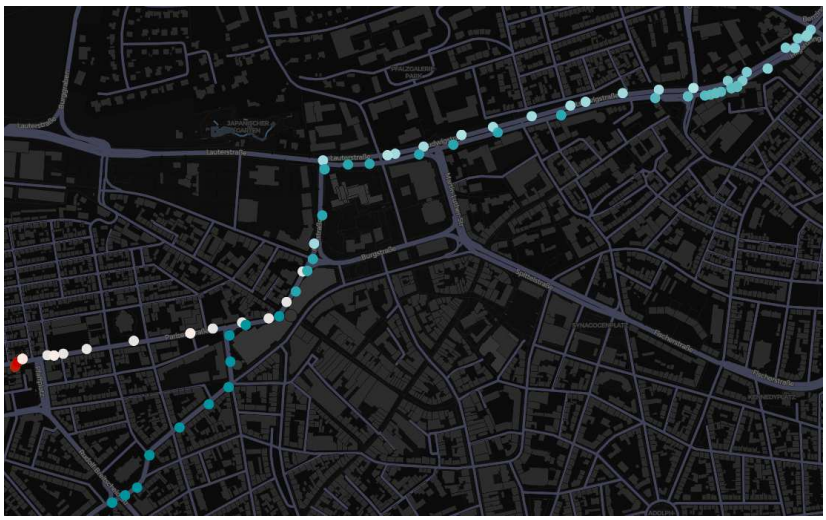

Abb. 4: Ein Pfad mit hohem Überschussquotienten, da sie in der Nähe des Startpunktes (blau) endet (rot). Es wird angenommen, dass hier kein Parksuchverkehr vorliegt.

6.3 True Negatives und False Positives

Es kann bei diesem Ansatz dazu kommen, dass Fahrten, die keinen Parksuchverkehr enthalten fälschlicherweise als solcher identifiziert werden (so genannte True Negatives). Das passiert immer dann, wenn Menschen in der Nähe des Zielorts einen Umweg fahren und nicht den direkten Weg einschlagen. Hierfür sind plausible Gründe denkbar, wie etwa Baustellen oder neue Verkehrsführungen, insbesondere Einbahnstraßen.

Umgekehrt kann es vorkommen, dass Fahrten mit Parksuchverkehr nicht erkannt werden, da sie vom Algorithmus nicht also solche kategorisiert werden (so genannte False Positives). Dies kann vorkommen, wenn nach der Parkplatzsuche ein Parkplatz direkt angesteuert wird, der weiter als 200m entfernt liegt, etwa in einem dem Fahrer bekannten Parkhaus. Darüber hinaus, werden kleine Parksuchwege, die weniger als das 1,5-fache der direkten Strecke in Anspruch nehmen nicht erkannt. Wenn der gefundene Parkplatz also nicht der optimale war, jedoch in unmittelbarer Nähe, kann dies der Algorithmus nicht erkennen.

7 ERGEBNISSE

Von den 9808 untersuchten Pfaden wurden 214 als Fahrten identifiziert, die mit Parksuchverkehr endeten und einen Überschussquotienten von kleiner fünf aufwiesen. Dies entspricht einer Quote von 2% im gesamten Untersuchungsraum. Die zusätzlich gefahrene Strecke allein durch Parksuchverkehr innerhalb dieses Datensatzes lag bei 245 km.

Wenn man davon ausgeht, dass es eine gleichmäßige Durchdringung von 5-10% gibt und man diesen Wert entsprechend skaliert, kommt man auf bis zu 4900 zusätzlich gefahrene Kilometer an diesem einen Samstag.

Es lässt sich feststellen, dass Parksuchverkehr sowohl im Zentrum als auch in den Ortsteilen und umliegenden Gemeinden vorkommt (vgl. Abb. 4).

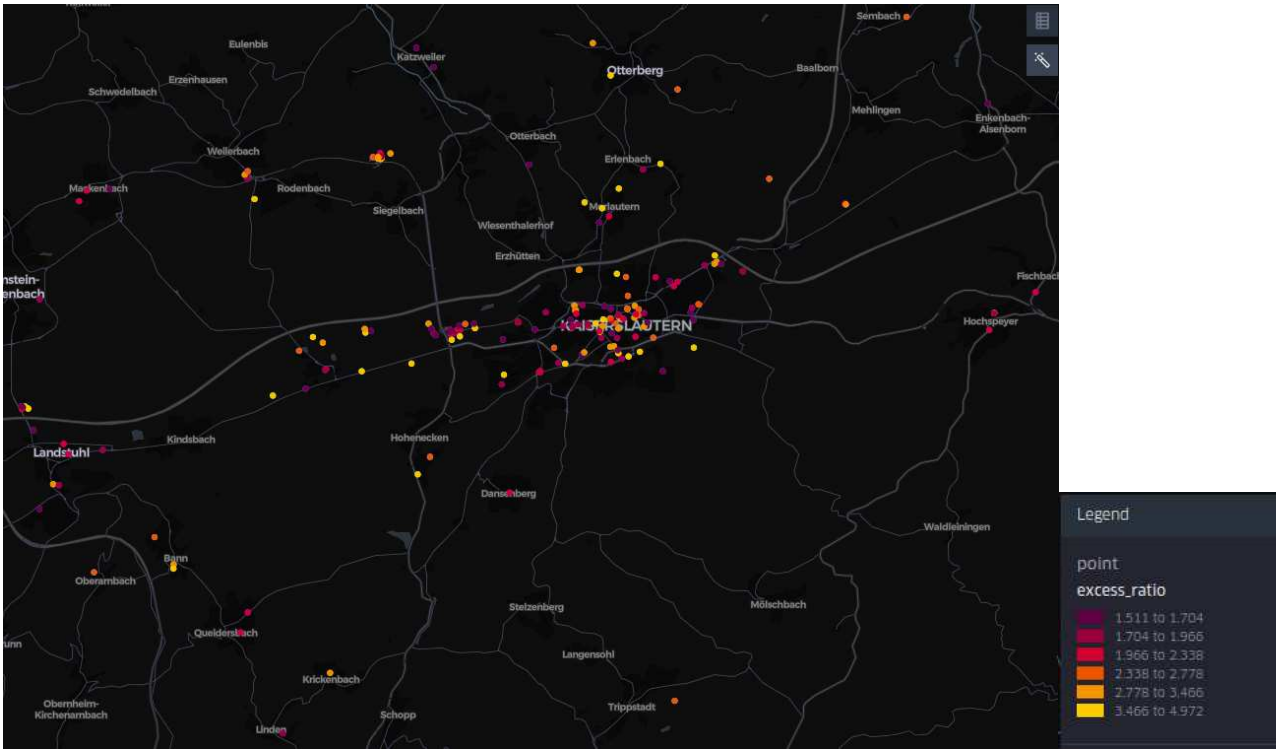

Abb. 5: Zielorte von Fahrten, die mit Parksuchverkehr endeten, im gesamten Untersuchungsraum.

Betrachtet man die Fahrten, die mit Parksuchverkehr endeten im Stadtgebiet von Kaiserslautern lassen sich bei der geringen Anzahl an Datenpunkten zunächst keine Auffälligkeiten erkennen (vgl. Abb. 6).

Abb. 6: Zielorte von Fahrten, die mit Parksuchverkehr im Stadtgebiet von Kaiserslautern endeten.

7.1 Kritik und Learnings

In den Prozess der Datenvorverarbeitung wurde erhebliche Zeit und Aufwand investiert, wodurch wertvolle Erkenntnisse über die Daten und ihre Qualität gewonnen wurden. Trotz dieser Bemühungen bestehen jedoch weiterhin Möglichkeiten zur Modifizierung und potenziellen Verbesserung. Beispielsweise könnte der Schritt zur Entfernung der Fußwege nach der Pfaderstellung erfolgen. Es bleibt jedoch unklar, ob ein ausgefeilterer Algorithmus in dieser Phase bessere Ergebnisse erzielen würde.

Für zukünftige Auswertungen wird empfohlen, Gebiete ohne Autobahnen zu wählen, sofern möglich, da die Datenminimierung in diesen Bereichen besonders aufwändig ist. Aufgrund der geringen Durchdringung der Daten ist es zudem ratsam, größere Zeiträume in Betracht zu ziehen.

Weiterhin sollten alternative Darstellungsarten der Ergebnisse gemeinsam mit Verkehrsplanerinnen und Verkehrsplanern erprobt werden, um eine umfassendere Analyse zu ermöglichen. Generell ist zu betonen, dass bei jeder Auswertung kritisch überprüft werden muss, ob die vorhandenen Daten tatsächlich für die angestrebten Zwecke nutzbar sind.

Eine auffällige Häufung von Fahrten lässt sich im Bereich des Industriegebiets nördlich von Siegelbach feststellen. Dies lässt sich darauf zurückführen, dass in diesem Gebiet ein Amazon-Zentrum ansässig ist und die detektierten Fahrten trotz eines Überschussquotienten kleiner als fünf Auslieferungen ohne erkennbaren Parksuchverkehr aufwiesen.

Die Auswertung nach Tageszeiten wurde aufgrund der begrenzten Datenmenge vorerst ausgelassen. Eine derartige Analyse wäre sinnvoller, wenn mehrere Tage betrachtet werden könnten, um zuverlässigere Schlüsse über zeitliche Muster ziehen zu können.

8 ZUSAMMENFASSUNG UND AUSBLICK

Floating Car Data (FCD) stellen für Verkehrsplanerinnen und Verkehrsplaner ein wertvolles Werkzeug dar, um detaillierte Einblicke in den Parksuchverkehr ihrer Kommune zu gewinnen. Bei der Nutzung von FCD sind jedoch einige wichtige Aspekte zu berücksichtigen. Eine sorgfältige Auswahl des Untersuchungsgebiets und des Untersuchungszeitraums ist ebenso entscheidend wie das Verständnis der Datenbeschaffung und -qualität, um die Ergebnisse korrekt einordnen und bewerten zu können.

Die Untersuchung eines einzelnen Tages, wie im Fall von Kaiserslautern am untersuchten Samstag im November 2022, lieferte weniger Erkenntnisse als erwartet, da keine Hotspots oder Auffälligkeiten identifiziert wurden. Dennoch kann diese Auswertung als Grundlage für vergleichende und aggregierte Betrachtungen dienen, die perspektivisch zu einem tieferen Verständnis führen können.

Durch die Analyse der zusätzlich zurückgelegten Strecken und die Anwendung geeigneter Modelle ist es möglich, die entstehenden zusätzlichen Emissionen zu ermitteln. Eine interessante Fragestellung ist zudem, welche Art von Verkehr mit Parksuchverkehr endet - kommt der Verkehr von außerhalb oder handelt es sich

um Binnenverkehr mit Fahrten, die auch in Kaiserslautern starten. Diese Auswertung ist mit den vorliegenden Daten möglich.

Ein Abgleich mit Verkehrszählungen oder Sensorerfassungen ist dringend ratsam, um die angegebene Durchdringung und mögliche Skalierung fundiert zu prüfen. Möglicherweise können Verkehrsforschende auch die Pfade nachvollziehen, die mit Parksuchverkehr enden, um Einblicke in das Verhalten der Autofahrenden zu gewinnen.

Überraschend war die Erkenntnis, dass der Algorithmus höchstwahrscheinlich Informationen über Taxifahrten und Fahrten von Lieferunternehmen liefern kann.

Für weitere Untersuchungen ist eine Anpassung der gewählten Konstanten Radius r = 400m bzw. der Eingrenzung des Überschussquotienten 1,5 < excess_ratio < 5 ist denkbar, vor allem wenn man im Vorfeld ein Map-Matching durchführt. Die Berücksichtigung weiterer verfügbarer Attribute wie etwa die Fahrtrichtung könnte eine Verfeinerung des Algorithmus liefern.

Abschließend lässt sich zusammenfassen, dass Floating Car Data eine wertvolle Datenbasis bilden, um Einblicke in den Verkehr und das Fahrverhalten von Autofahrenden zu gewinnen, vorausgesetzt, man berücksichtigt einige Aspekte, zieht keine voreiligen Schlüsse und ist sich der Besonderheiten der Daten bewusst.

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🏆 *reviewed paper*

Decoding Stress – ein interdisziplinärer Analyseansatz zur Identifikation Stress auslösender Faktoren für den urbanen Rad- und Fußverkehr

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1 ABSTRACT

Wie nehmen wir Stadträume wahr, wenn wir mit dem Fahrrad oder zu Fuß unterwegs sind? An welchen Orten in der Stadt fühlen wir uns wohl, respektive unwohl und gestresst? Welche spezifischen Faktoren beeinflussen dabei unsere Emotionen? Und vor allem: Mit welchen Methoden können diese Einflussfaktoren entschlüsselt werden?

Ausgehend von den Emo-Cycling-Stressmessungen der Urban Emotions Initiative (Zeile et al., 2014). untersucht die Studie „Decoding Stress“ auffallende Stress-Hotspots für Radfahrende im urbanen Kontext. Im Fokus steht dabei die Entwicklung eines interdisziplinären und multimodalen Analyseansatzes zur Erweiterung der Stressorenanalyse. Neben diversen digitalen Analysemethoden beschäftigt sich der vorgestellte Forschungsansatz dabei intensiv mit der Erweiterung der Methodik um einen bislang vorwiegend im Bereich der Architektur und Stadtplanung bekannten, „analogen“ Werkzeugkasten (Eckart, 2014). Mithilfe dieses Methodenmix erprobt die Studie einen holistischen Analyseansatz, der erstmals quantifizierbare „harte“ Faktoren und qualifizierbare „weiche“ Faktoren gleichermaßen berücksichtigt. Die gewonnenen Erkenntnisse leisten einen Beitrag dazu, die interdisziplinäre Zusammenarbeit von Stadt- und Verkehrsplanung zu fördern und gemeinsame Lösungsansätze für qualitätsvolle und menschengerechte öffentliche Stadträume zu erarbeiten.

In diesem Beitrag werden die im Jahr 2023 durchgeführten Stressorenanalysen aus den vier Fallstudien in den Untersuchungsstädten Karlsruhe und Osnabrück vorgestellt und miteinander verglichen. Dabei werden die angeführten Analysen einerseits inhaltlich hinsichtlich erster gewonnener Erkenntnisse ausgewertet und andererseits die angewandte Methodik evaluiert und hinsichtlich einer möglichen Weiterentwicklung geprüft.

Keywords: Emotion Sensing, aktive Mobilität, Stressforschung, Stadtwahrnehmung, Stadtplanung

2 EINLEITUNG

2.1 Stadt, Mobilität und Lebensqualität

Seit der Errungenschaft des Autos und dem damit verbundenen autogerechten Umbau unserer Städte in den 60er Jahren hat sich das Mobilitätsverhalten unserer Gesellschaft stark gewandelt. Trotz der unveränderten Beliebtheit des Autos, das in Deutschland immer noch für rund 57 Prozent aller Wege genutzt wird (BMVI, 2018), gewinnen aktive Mobilitätsformen, wie zum Beispiel der Radverkehr, vor allem in den urbanen Ballungsgebieten jeeoch zunehmend an Bedeutung. Aber auch erst kürzlich neu hinzugekommene Verkehrsmittel wie Pedelecs, E-Roller und Lastenräder konfrontieren den öffentlichen Raum mit neuen Herausforderungen. Diese zunehmende Überlastung unserer öffentlichen Räume beginnt sich jedoch zunehmend in Form von Staus, Luftverschmutzungen und steigenden Unfallzahlen negativ auf die Lebensqualität in den Städten auszuwirken. Sowohl die Politik, als auch die Verwaltung und Planung sehen sich deshalb nunmehr dazu aufgefordert, sich diesem Problem zu stellen und nachhaltige, menschengerechte Lösungen für die Mobilität in unseren Städten zu entwickeln. Im Rahmen dieser „Rückeroberung“ des öffentlichen Raums durch den Menschen, ist es dabei vor allem der Rad- und Fußverkehr (auch: „Langsamverkehr“), der im urbanen Raum als eine gesunde, flächensparende und vor allem klimafreundliche Form der Mobilität (BMDV, 2022), eine Schlüsselrolle einnimmt.

An der aktuellen Aufteilung des bundesweiten Modal Splits nach Raumtypen (BMVI, 2018) lässt sich diesbezüglich gut erkennen, welche Wichtigkeit dabei dem Faktor Urbanität beizumessen ist. In Abbildung 1 werden die Langsamverkehrsanteile im Vergleich zu den restlichen Verkehrsmitteln (Auto und ÖPNV) dargestellt. Festzustellen ist dabei, dass der Anteil des Langsamverkehrs am Gesamtverkehrsaufkommen in

Metropolen bei überdurchschnittlichen 42 Prozent liegt, wohingegen er in ländlichen Regionen im dörflichen Raum nur rund 24 Prozent beträgt. Dieser extreme Unterschied lässt sich zum Großteil durch das vielfältige und gut erreichbare Anbegot im urbanen Raum begründen. Denn ganz nach dem Leitbild der 15-Minuten-Stadt (Kurth, 2021) werden aktive Mobilitätsformen vorrangig innerhalb solcher Raumtypen genutzt, in denen die Wegstrecken nur wenige Kilometer betragen.

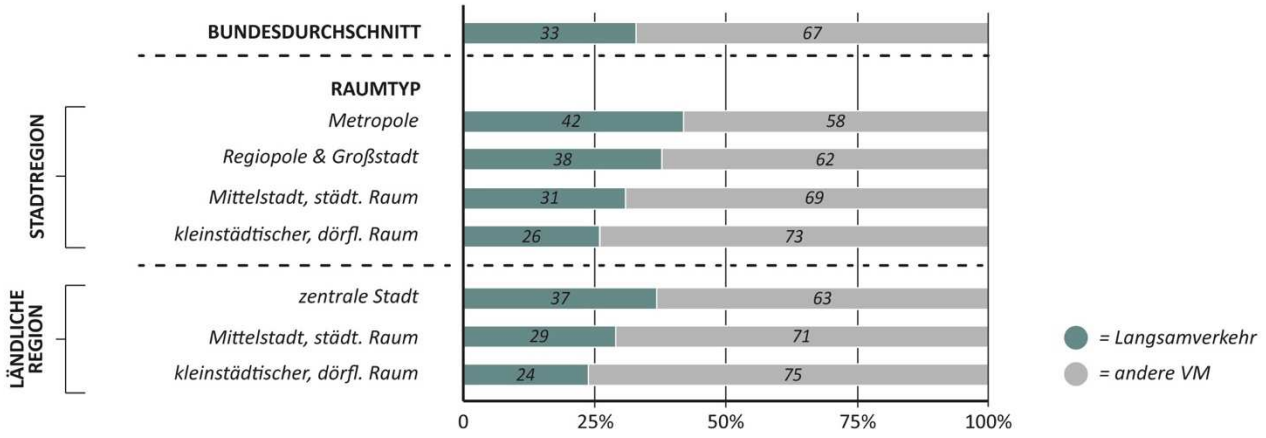

Abb. 1: Langsamverkehrsanteile im Modal Split nach Raumtypen. (Quelle: Eigene Darstellung nach Datenquelle BMVI, 2018)

Darüber hinaus wird die Entscheidung der Nutzerinnen und Nutzer für oder gegen das Fahrrad, beziehungsweise das Zufußgehen, jedoch maßgeblich auch von Aspekten des Wohlbefindens und Sicherheitsempfindens beeinflusst. In diesem Kontext konstatiert auch der Nationale Radverkehrsplan 3.0, dass sich eine Person nur dann für ein Verkehrsmittel entscheidet, wenn sie dieses subjektiv als sicher einstuft (BMDV, 2022).

2.2 Identifikation symptomatischer Räume

In Bezug auf die Förderung aktiver Mobilitätsformen im urbanen Kontext wird es zukünftig immer wichtiger werden, stressfreie Umgebungen für den Rad- und Fußverkehr zu schaffen. Es erscheint daher evident, dass der Identifikation und Untersuchung von neuralgischen Stresspunkten für den Rad- und Fußverkehr eine zentrale Rolle zugeschrieben werden muss. In diesem Kontext stellt die Methode des Emotion Sensings, beziehungsweise auf das Fahrradfahren bezogen die EmoCycling-Methode, seit einigen Jahren eine bedeutende Innovation in der Stadtplanung (Polis Magazin, 2022) dar. Mithilfe dieser Stressmessungen ist es schließlich gelungen, das subjektive Empfinden von Probanden während ihrer Bewegung durch die Stadt anhand biostatistischer Marker objektiv messen zu können (Höffken et al., 2014; Zeile et al., 2014). Die Ergebnisse der Messungen werden als Heatmaps visualisiert und bieten standortgenaue Informationen darüber, an welchen Punkten die Probanden Stress, respektive keinen Stress empfunden haben. Allerdings können mithilfe dieses Verfahrens keine Rückschlüsse auf die Ursachen, die die physiologisch messbare Stressreaktion bei den Probanden ausgelöst haben, gezogen werden.

2.3 Forschungslücke Stressorenanalyse

Die dringend erforderliche Ursachenforschung (Stressorenanalyse), die auf diesen Erkenntnissen aufbaut, steht derzeit jedoch noch am Anfang ihrer Entwicklung Die Mehrheit der in diesem Kontext angeführten Studien fokussieren sich in diesem Zusammenhang jedoch auf eine reine Analyse der Verkehrssituation, wie beispielsweise der Untersuchung von Führungsformen und Spurbreiten. Vereinzelt wird dabei auch auf „digitalen“ Analysetools, meist in Form von Entwicklungen aus der Sensorik, zurückgegriffen. Diese berücksichtigen allerdings ausschließlich quantifizierbare „harte“ Faktoren und können im Rahmen einer Ursachenforschung lediglich ein fragmentarisches Bild der Situation liefern.

Im Gegensatz dazu verfolgt der Ansatz der hier vorgestellten Studie das Ziel, den Einfluss qualifizierbarer „weicher“ Faktoren und die damit verbundenen Einsatzmöglichkeiten „analoger“ Analysemethoden näher zu erforschen. Mithilfe eines multimodalen und interdisziplinären Ansatzes soll es dadurch ermöglicht werden, die spezifischen räumlichen Situationen der identifizierten Stress-Hotspots ganzheitlich zu betrachten. Dabei sollen erstmals nicht nur verkehrsplanerische, sondern auch stadträumliche Faktoren berücksichtigt werden.

3 STAND DER FORSCHUNG

3.1 Das Phänomen Stress

3.1.1 Stress als physiologische Reaktion des menschlichen Körpers

Nach dem gängigen Stressmodell von Selye wird Stress als die Summe aller Anpassungsvorgänge und Körperreaktionen bezeichnet, mit denen ein Lebewesen auf seine Umwelt reagiert (Selye, 1956). Übertragen auf den Menschen bedeutet dies, dass das Erleben einer Stresssituation zu einer biophysiologischen Reaktion im menschlichen Körper führt. Diese Reaktion läuft wie folgt ab: Wird der Mensch einem Stimulus ausgesetzt und empfindet dadurch Stress, so schüttet der Körper Hormone aus, die bestimmte Teile des Nervensystems (HHN-Achse und autonomes Nervensystem) aktivieren. Damit versucht der Körper, den Stress auszugleichen und den Zustand der Homöostase, also einen „stabilen" Zustand, wiederherzustellen. Für diese Anpassung verändert der Körper mitunter die Herztätigkeit, Schweißdrüsenaktivität und die Hauttemperatur (Chrousos et al., 1988; Boucsein, 1988; Kreibig, 2010). Diese messbaren physiologischen Signale können als Indikatoren eindeutig in Verbindung mit der Reaktion des menschlichen Körpers auf eine Stresssituation gebracht werden (Karthikeyan et al., 2013). Heutige Messungen im Kontext des Emotion Sensings greifen hauptsächlich auf die Elektrodermale Aktivität (EA) zurück, die als empfindlichster und zuverlässigster Marker für eine emotionale Erregung (Kyriakou, Resch, et al., 2019) gilt.

3.1.2 Stress im urbanen Kontext

Die Wahrnehmung seiner Umwelt ist stark im Inneren des Menschen verwurzelt. Wenn sich der Mensch durch einen Raum bewegt, ist er unterbewusst stetig damit beschäftigt, die auf ihn einwirkenden Umweltreize zu verarbeiten und sich ein inneres Bild seiner Umwelt anzufertigen (Lynch, 1965). Zurückzuführen ist der Vorgang dieser inneren Verbildlichung dabei auf das natürliche Bedürfnis des Menschen nach Orientierung, beziehungsweise der Notwendigkeit eines Bezugssystems, das für seine ursprüngliche Lebensweise überlebensnotwendig war. Noch heute bezieht sich die menschliche wahrnehmung seiner Umwelt, respektive sein Bild der Stadt, deshalb auf ihm bekannte, wiederkehrende und ablesbare Elemente. Zur Erkennung dieser Elemente und Verarbeitung der auf ihn einwirkenden Umweltreize aktiviert der Mensch deshalb unterbewusst all seine Sinne. Je nachdem, ob im Rahmen dieser unterbewussten Verarbeitung eine positive oder negative Wahrnehmung überwiegt, empfindet der Mensch dann Sicherheit und Wohlbefinden oder Unbehagen (Mehrabian, 1987).

Die Umwelt „Stadt" gilt in diesem Zusammenhang als eine der komplexesten Umwelten mit einem äußerst hohen Reizvolumen für den Menschen (Mehrabian, 1987). In unseren heutigen Stadträumen sind wir demnach einer solch enormen Masse an Reizen ausgesetzt, dass sich die Auswirkungen von einzelnen Reizen auf unser Empfinden kaum noch herausfiltern lassen. Bei der Stressforschung im urbanen Kontext muss deshalb immer das Zusammenspiel unterschiedlicher Faktoren und dessen Auswirkungen auf das menschliche Empfinden betrachtet, beziehungsweise eine Art von „Rauschen" mitberücksichtigt werden.

3.1.3 Stressdetektion mithilfe der EmoCycling-Methode

Das Messen, Verorten und Visualisieren von Stress im urbanen Kontext sind die Grundpfeiler der heute in zahlreichen Forschungsprojekten angewandten Methodik des Emotion Sensings, beziehungsweise des EmoCyclings (Zeile et al., 2021; Haug et al., 2023a). Die Ursprünge dieser Methode gehen dabei auf Christian Nold zurück, der für seine „emotionalen Kartografien" im Jahr 2009 ein eigenes „Bio-Mapping"-Gerät (Nold, 2009) entwickelte. Damit wurde es erstmals möglich, die messbaren Stress-, beziehungsweise Erregungszustände georeferenziert innerhalb eines situativ-räumlichen Kontexts aufzuzeichnen und visualisieren.

In den späten 2000er Jahren wurden die Methode dann von der Urban Emotions Initiative an der TU Kaiserslautern und der Universität Heidelberg mit einem ähnlichen Aufbau erprobt und erste Stadtkartierungen vorgenommen (Zeile et al., 2010). Später wurde dieser Ansatz vor allem am Karlsruher Institut für Technologie (KIT) und der Paris Lodron Universität Salzburg (PLUS) weiterentwickelt. Schnell konnte im Rahmen dieser ersten Annäherungen festgestellt werden, dass sich die Methode mit der sekundengenauen Messung des emotionalen Zustands der Probanden auch bestens für die Anwendung im Kontext des Fahrradfahrens (Höffken et al., 2014) eignet.

Das Setting der seither als „EmoCycling“ bekannten Methodik wurde daraufhin weiter optimiert und erzielte schnell einen Durchbruch in der Radverkehrsforschung. Die Messungen werden nunmehr lediglich mithilfe eines Sensorarmbandes (Empatica E4) und einem Smartphone durchgeführt (Zeile et al., 2021; Zeile et al, 2022; Werner et al., 2019). Das Sensorarmband misst dabei die Vitaldaten der Probanden (Hautleitfähigkeit und Hauttemperatur), synchonisiert diese mithilfe des Smartphones mit den dazugehörigen GPS-Daten und sammelt sie in einer App. Das Auswertungsmuster ist seit den Anfängen der Methodik unverändert: Eine Stressreaktion, auch Moment of Stress (MOS) genannt, wird dann identifiziert, wenn direkt nach einem Reiz ein temporärer Anstieg der Hautleitfähigkeit in Kombination mit einem Absinken der Hauttemperatur messbar ist.

Abb. 2: Heatmap als Ergebniskarte der EmoCycling-Messungen in Karlsruhe (links) und Setting mit Smartband Empatica E4 und Smartphone (rechts). (Quelle: Eigene Darstellung nach Datenquelle Cape Reviso)

Die ausgewerteten Datensätze werden daraufhin mithilfe eines Geoinformationssystems (GIS) georeferenziert dargestellt und einer Kerndichteschätzung (KDE) unterzogen, um räumliche Cluster zu ermitteln. Die so entstehende Visualisierung der Ergebnisse wird umgangssprachlic auch als „Heatmap“ bezeichnet. Über die verwendete Farbcodierung der Heatmap kann dann ausgewertet werden, in welcher Intensität und an welcher geografischen Position die Probanden Stress, beziehungsweise keinen Stress empfunden haben. Die entsprechend der Farbcodierung rot dargestellten Punkte, sogenannte „Hot-Spots“, symbolisieren dabei eine Konzentration der gemessenen Stressmomente, wohingegen in den blau dargestellten Bereichen verhältnismäßig weniger Stressmomente gemessen wurden.

3.2 Stressorenanalyse

Im Kontext der Stressorenanalyse ist bislang eine starke Ausrichtung auf verkehrsspezifische Faktoren und deren Erhebung mithilfe von digitalen Analysemethoden zu beobachten. Die Einsatzmöglichkeiten von analogen, beziehungsweise grafisch und visuell arbeitenden, Analysemethoden, wie sie aus der Stadtforschung und -planung bekannt sind, bleiben in diesem Kontext jedoch noch weitestgehend unerforscht. Im Folgenden soll ein Überblick über sowohl die bisherigen Ansätze aus der Radverkehrsforschung, als auch über allgemeine Ansätze zur Erforschung von Stadträumen aus der Stadtforschung gegeben werden.

3.2.1 Ursachenforschung in der Radverkehrsforschung mithilfe „digitaler“ Analysemethoden und Crowdsourcing-Ansätzen

Mit ihrem Forschungsfeld der Radverkehrsforschung gilt die Disziplin der Verkehrsplanung als Vorreiter der Stressorenanalyse. Insbesondere was das sensorengestützte Messen verkehrsspezifischer Faktoren anbelangt, kann hier mittlerweile auf ein relativ großes Methodenspektrum zurückgegriffen werden. Zu nennen sind hier beispielsweise Entwicklungen wie der OpenBikeSensor (OpenBikeSensor, 2023) zur Abstandsmessung bei Überholvorgängen, beziehungsweise sein Pate, der Radmesser (Tagesspiegel, 2018). Aber auch experimentelle Ansätze, wie der Einsatz von Eye-Tracking-Geräten zur Überprüfung der Blickerfassung von Beschilderungen (Walther et al., 2022) kommen in ersten Studien zum Einsatz. Aber hinsichtlich einer simultanen Erhebung mehrerer Untersuchungsparameter gibt es erste Studienansätze, wie zum Beispiel das von der Hochschule Karlsruhe entwickelte „SensorBike“ (Temmen, 2020). Als multisensorisches Messfahrrad sind im SensorBike mitunter ein Leistungsmesser, Vitalsensoren, Beschleunigungs- und

Erschütterungssensoren, ein Abstandsmesser und Kameras, sowie Sensoren zur Erhebung spezifischer Umweltfaktoren. Vor allem durch die Verknüpfung der verschiedenen gesammelten Datensätze können im Kontext der Auswertung neue Erkenntnisse für die Stressorenanalyse generiert werden.

In den letzten Jahren konnte darüber hinaus auch durch die zunehmend auch im Freizeit-Radsport ankommende Digitalisierung neue Möglichkeiten zur partizipativen Datenerfassung und -auswertung (Lißner et al., 2018) experimentiert werden. In diesem Kontext bietet insbesondere das Smartphone als ein ubiquitärer und multifunktionaler Sensor (Eckart et al., 2020) mannigfaltige Möglichkeiten, um spezifische Bewegungs- und Umweltdaten zu erheben. Verschiedene, meist frei verfügbare Applikationen bieten hier eine sehr niederschwellige Anwendungsmöglichkeit. Darüber hinaus konnten auch durch die wachsende Beliebtheit sozialer Sport-Netzwerke erste Erfolge in der Nutzung von Big Data in der Radverkehrsforschung erzielt werden. Insbesondere die Radverkehrsdatensätzen der Provider „Strava“ und „BikeCitizens“ bieten hinsichtlich der Evaluation kommunaler Radverkehrsnetze zahlreiche Anwendungsmöglichkeiten (Lißner et al., 2018). Mit den Analysefunktionen der beiden Provider können zum Beispiel die analysierten Fahrgeschwindigkeiten und die Wartezeiten an Ampeln direkt mit gemiedenen, beziehungsweise bevorzugten Streckenabschnitten in Beziehung gesetzt werden.

3.2.2 Analysemethoden aus der Stadtforschung

Als ein interdisziplinäres Forschungsfeld steht die Stadtforschung im engen Zusammenhang sowohl mit der Geografie, der Anthropologie, der Soziologie und der Ethnologie, als auch mit einigen anderen raumbezogenen Forschungsfeldern (Pelger et al., 2021). Im Kontext ihres Forschungsgegenstandes ist diese Interdisziplinarität notwendig, um das komplexe Raumgefüge Stadt nicht nur beschreibend in ihrer Theorie, sondern auch in ihrer Dynamik als ein sich stetig verändernder Raum zu durchdringen. In der Erforschung von Stadt gibt es deshalb kein vordefiniertes Forschungsdesign, wie es in anderen wissenschaftlichen Disziplinen Usus ist, sondern es wird meist auf eine Kombination unterschiedlicher Methoden zurückgegriffen (Eckardt, 2014). Innerhalb der Stadtforschung kann somit auf einen breiten Fächer an Analysemethoden und entsprechender Darstellungsmöglichkeiten zurückgegriffen werden, die je nach Umfang und Art der Aufgabe ganz unterschiedliche Analyseaspekte und Detailtiefen bearbeiten können. Mitunter sind dabei Interviews, Beobachtungen, Kartierungen, Mappings, Fotografien und künstlerische Annäherungen als gängige Methoden zu nennen (Eckardt, 2014). Die mithilfe dieser visuellen und grafischen Methoden entstehenden Analysegrafiken können im Rahmen komplexer Aufgabenstellungen dabei helfen, die Grenzen des digital Erfassbaren, beziehungsweise quantitativ Messbaren zu überwinden.

In diesem Zusammenhang geht es bei der Erforschung von Stadträumen jedoch nicht nur um eine Erhebung und Analyse vorhandener raumbezogener Daten, sondern insbesondere um ein In-Beziehung-Setzen der Daten (Pelger et al., 2021). Im Rahmen von Mixed-Methods-Ansätzen können so zum Beispiel durch die Kombination von räumlichen Darstellungen mit anderen Datensätzen, respektive Werkzeugen, wie zum Beispiel abstrahierten Illustrationen oder fotografischen Annäherungen, neue Erkenntnisse gewonnen werden.

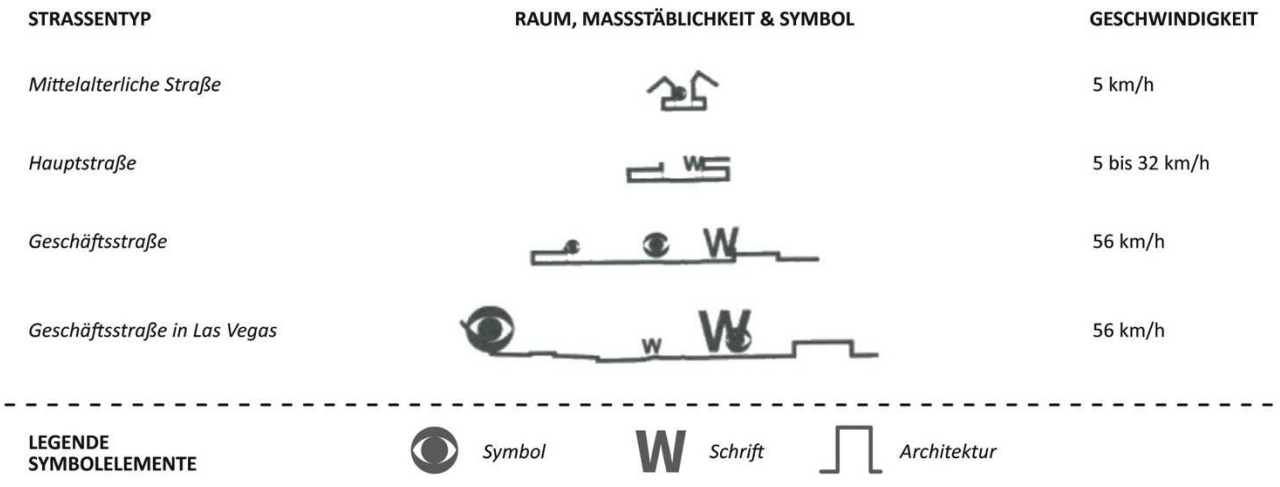

Abb. 3: Schnittanalyse verschiedener Straßenräume im Vergleich zu Las Vegas in Bezug auf Raum, Maßstab, Symbol und Geschwindigkeit. (Eigene Darstellung nach Venturi et al., 1979; Beschriftung und Anordnung der Ursprungsgrafik verändert)

Abbildung 3 zeigt in diesem Kontext eine frühe analytische Annäherung Robert Venturis Ende der 70er Jahre (Venturi et al., 1979), die im Kontext der Analyse von Straßenräumen und Symbolik der Geschäftsstadt Las Vegas durchgeführt wurde. Dabei kombiniert Venturi nach dem Mixed-Methos-Ansatz eine Schnittanalyse mit der abstrahierten Darstellung der vor Ort beobachteten Symbolik und den Bewegungsgeschwindigkeiten. Durch die vergleichende Darstellung und die Kombination der analysierten Inhalte wird in der Analysegrafik die Beziehung zwischen verschiedenen Bewegungs-, beziehungsweise Fahrgeschwindigkeiten und der daran angepassten Dimension von Stadträumen und Symbolen deutlich.

4 ANWENDUNG DES INTERDISZIPLINÄREN STRESSFORSCHUNGSANSATZES

4.1 Aufbau und Durchführung der Studie

Im folgenden Abschnitt, der sich dem Aufbau und der Durchführung der Studie widmet, wird sowohl auf die Auswahl und den Aufbau der Fallstudien eingegangen, als detailliert die Entwicklung der Methodik erläutert.

4.1.1 Datengrundlage der Untersuchungen: EmoCycling-Heatmap

Als eine wichtige Grundlage dienen der Studie die Heatmaps der EmoCycling-Stressmessungen aus den aktuellen Projekten der Urban Emotions Initiative „Cape Reviso“ innerhalb der Untersuchungsstadt Karlsruhe (Zeile et al., 2021), sowie „ESSEM“ innerhalb der Untersuchungsstadt Osnabrück (Haug et al., 2023). Die entstandenen Heatmaps dienen der vorliegenden Studie als ein erster Überblick über die neuralgischen Stress-Hotspots und bilden die Grundlage für die Auswahl der Fallstudien.

Die EmoCycling-Messungen in Karlsruhe wurden im Winter 2021/22 durchgeführt. Dabei wurden die Stressreaktionen von insgesamt 17 Radfahrenden auf einer vorgegebenen Route gemessen. Nach Abzug einiger fehlerhafter Datensätze konnten bei dieser Erhebung 26 Tracks gesammelt werden und dabei 1121 Moments of Stress detektiert werden. In Osnabrück kann hingegen auf einen deutlich umfangreicheren Datensatz zurückgegriffen werden. Die Messungen wurden hier mehrphasig als Freifahrten konzipiert und im Herbst 2022 durchgeführt. Die 28 teilnehmenden Probanden sammelten auf ihren alltäglichen Fahrradfahrten insgesamt rund 480 Tracks. Dabei konnten rund 13.000 Stressmomente gemessen werden.

4.1.2 Strukturanalysen in den Untersuchungsstädten Karlsruhe und Osnabrück

Im weiteren Verlauf setzt die Studie Decoding Stress die vorliegenden Heatmaps in Beziehung mit den prägenden Strukturelementen Karlsruhes und Osnabrücks (siehe Abbildung 4). Methodisch werden dabei frei verfügbare Datensätze der Plattform OpenStreetMap zu verschiedenen Themenbereichen, wie zum Beispiel zu Freiraumnetz, Baustruktur und Nutzungsverteilungen, in einem GIS-Programm inhaltlich und grafisch aufbereitet. Durch das Rückkoppeln der verschiedenen Strukturelemente mit dem Layer der EmoCycling-Heatmap können daraus auffällige Räume identifiziert werden, die sich als potentielle Fallstudien für die Stressorenanalyse eignen. In diesem Zusammenhang ist es wichtig hervorzuheben, dass bei diesem Prozess nicht allein die Intensitäten der Stress-Hotspots entscheidend waren, sondern vor allem auch stadtstrukturell und räumlich bedeutsame Orte ausgewählt wurden.

In diesem Zusammenhang werden in der „Fächerstadt“ Karlsruhe insbesondere die räumlichen Schnittstellen zu den prägenden „Strahlen“ als potentielle Untersuchungsgebiete identifiziert. Darüber hinaus konnten entlang dieser Strahlenstruktur vor allem die hochfrequentierten Bereiche des Zentrums, in denen sich eine Vielzahl an Nutzungen ballen, als symptomatische Räume identifiziert werden. In Osnabrück sind es hingegen vor allem die Verbindungen, die über die mehrspurige Ringstraße in Richtung des historischen Zentrums führen.

4.1.3 Auswahl der Untersuchungsgebiete K1, K2, O1 und O2 als Fallstudien

Nach diesem Auswahlverfahren werden in den beiden Untersuchungsstädten jeweils zwei Stadträume als Untersuchungsräume für die Fallstudien definiert. Abbildung 4 zeigt in diesem Zusammenhang eine Übersicht für die Stadt Karlsruhe. Für die Untersuchungsstadt Karlsruhe wird die erste Fallstudie „K1“ auf dem Bereich um den Ludwigsplatz definiert, der sich im westlichen Teil des Stadtzentrums befindet. Neben den stadtstrukturell prägenden Elementen, dem Verlauf wichtiger Fahrradrouten und der hohen Frequentierung können in diesem Gebiet verschiedene Raumansprüche und -konflikte beobachtet werden. Der Bereich um den Lidellplatz, beziehungsweise entlang des Strahls der Adlerstraße, wird als Fallstudie „K2“ definiert. Dieser Stadtraum weist eine deutlich geringere Nutzungsdichte auf und ist weniger von

Zufußgehenden frequentiert. Der Lidellplatz ist als autofreie Zone ausgewiesen, entlang der Adlerstraße wird der Radverkehr jedoch gemeinsam mit dem MIV geführt und beidseitige Parkzonen ausgewiesen.

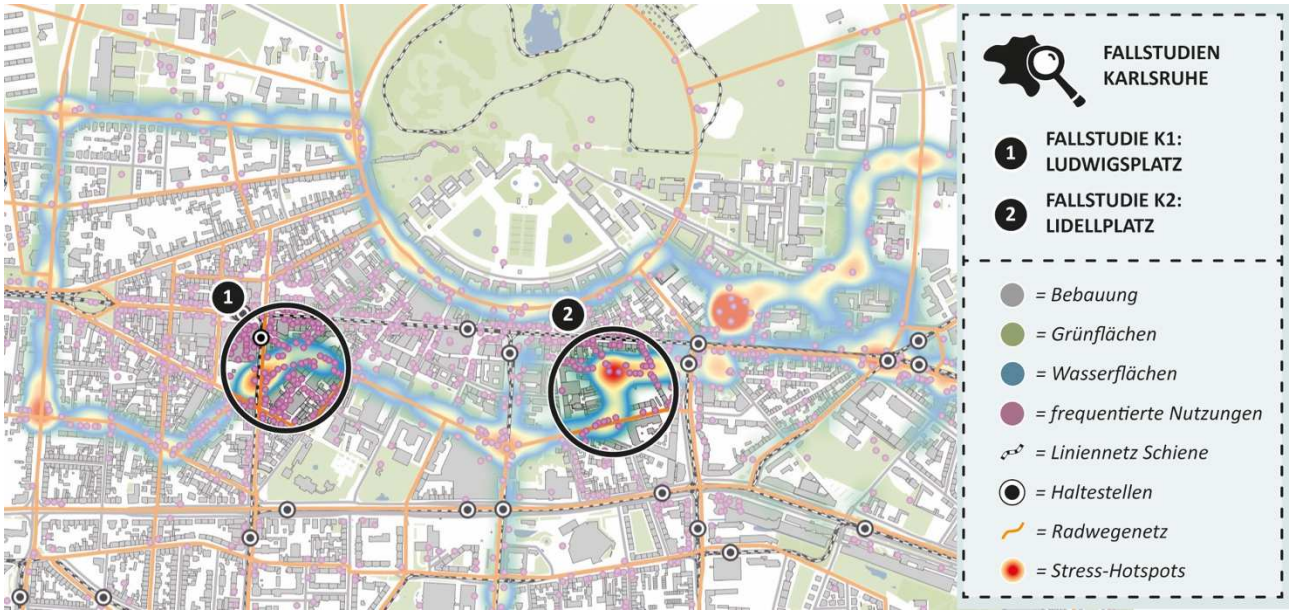

Abb. 4: Strukturanalyse und Auswahl Fallstudien Stadt Karlsruhe. (Quelle: Eigene Darstellung nach Datenquelle OpenStreetMap, Heatmap nach Datenquelle Cape Reviso)

In Osnabrück wurden nach der gleichen Vorgehensweise daraufhin zwei Bereiche im nördlichen Stadtzentrum für die Fallstudien ausgewählt. Als Fallstudie „O1“ wurde dabei der nördliche Stadteingang definiert. Der Radverkehr wird hier über die Hauptverkehrsachse des Wallrings und die Kunsthalle in Richtung Innenstadt geführt, und wird vor Beginn der Fußgängerzone in einer scharfen Kurve nach Osten umgeleitet. In diesem Stadtraum sind vor allem die historisch bedingten, kleinteiligen Baustrukturen und geringen Straßenquerschnitte von besonderem Interesse. Die Fallstudie „O2“ behandelt den Bereich entlang der Dielingerstraße und der Lortzingstraße. Hier sind vor allem die kreuzende Fußgängerzone, die gemeinsame Führung mit dem Busverkehr, sowie der weitläufige Platz des Domhofs von Bedeutung.

4.1.4 Testlauf in Fallstudie K1 im April 2023

Der interdisziplinäre Ansatz der Studie Decoding Stress wurde zunächst im April 2023 im Rahmen einer ersten Annäherung innerhalb des Untersuchungsgebiets K1 in Karlsruhe erprobt. Im Rahmen dieses Testlaufs wurde mit einem Pool aus 23 potentiellen Einflussfaktoren und verschiedenen, explorativen Analysemethoden experimentiert (Haug et al., 2023b). Dabei konnte die Erkenntnis gewonnen werden, dass vor allem durch die Kombination aus objektiven Bestandsaufnahmen und dem Mapping der eigenen, subjektiven Eindrücke und Wahrnehmungen ein Mehrwert für die Stressorenanalyse entsteht. Die Untersuchungsergebnisse des Testlaufs wurden in einer einheitlichen Form mithilfe von räumlichen Analyseplänen, einer fotografischen Dokumentation und einer schematischen Übersetzung der Ergebnisse dokumentiert (Haug et al., 2023c).

4.1.5 Untersuchungsfaktoren und Analysemethoden

Mit der Auswertung der Ergebnisse des Testlaufs konnten für die geplanten Erhebungen in den vier Fallstudien 12 Untersuchungsfaktoren mit ihren dazugehörigen Unterparametern als Gegenstand der im Sommer 2023 durchgeführten Fallstudien festgehalten werden. Abbildung 5 zeigt die Faktoren und ihre Zuordnung in fünf grundlegende Themenbereiche. Neben baulichen, freiraumspezifischen, gestalterischen und verkehrlichen Faktoren werden dabei für die Studie Decoding Stress auch sensuelle Faktoren, wie zum Beispiel die Wahrnehmung von Gerüchen, Geräuschen und Lärm als Untersuchungsfaktoren definiert.

In einem nächsten Schritt wurden dann für jeden Untersuchungsfaktor mithilfe der Ergebnisse des Testlaufs adäquate Analysemethoden evaluiert und in einem Datenerhebungsplan festgehalten. Dabei kann grundlegend zwischen der „digitalen“ Analyse mithilfe von frei verfügbaren OpenStreetMap-Datensätzen und Luftbildern und der „analogen“ Analyse durch Begehungen und ihrer Dokumentation in Mappings unterschieden werden. Bei einigen Faktoren wurden die beiden Methoden auch miteinander kombiniert.

Abb. 5: Untersuchungsfaktoren und Unterparameter nach Themengebieten.

4.1.6 Übersetzungsmethodik

Aufgrund des verfolgten interdisziplinären Ansatzes, ist es ein besonderes Anliegen der Studie, die einzelnen Ergebnisse der durchgeführten Erhebungen in einer möglichst vergleichbaren Form zu visualisieren. Abbildung 6 zeigt in diesem Zusammenhang, wie das räumliche Grundgerüst einer jeden Fallstudie hierzu zunächst in eine Bewegungslinie und die abgehenden Straßenkreuzungen und -einmündungen seziert wird. In einem nächsten Schritt wird aus diesen Elementen dann ein Schema übersetzt, das die Bewegungslinie als x-Achse und die abgehenden Straßen als Fixpunkte markiert. In der so entstehenden „Stressorenabwicklung“ können dann die verschiedenen Ausprägungen der analysierten Parameter mittels einer individuell gewählten Skala auf der y-Achse eingetragen werden.

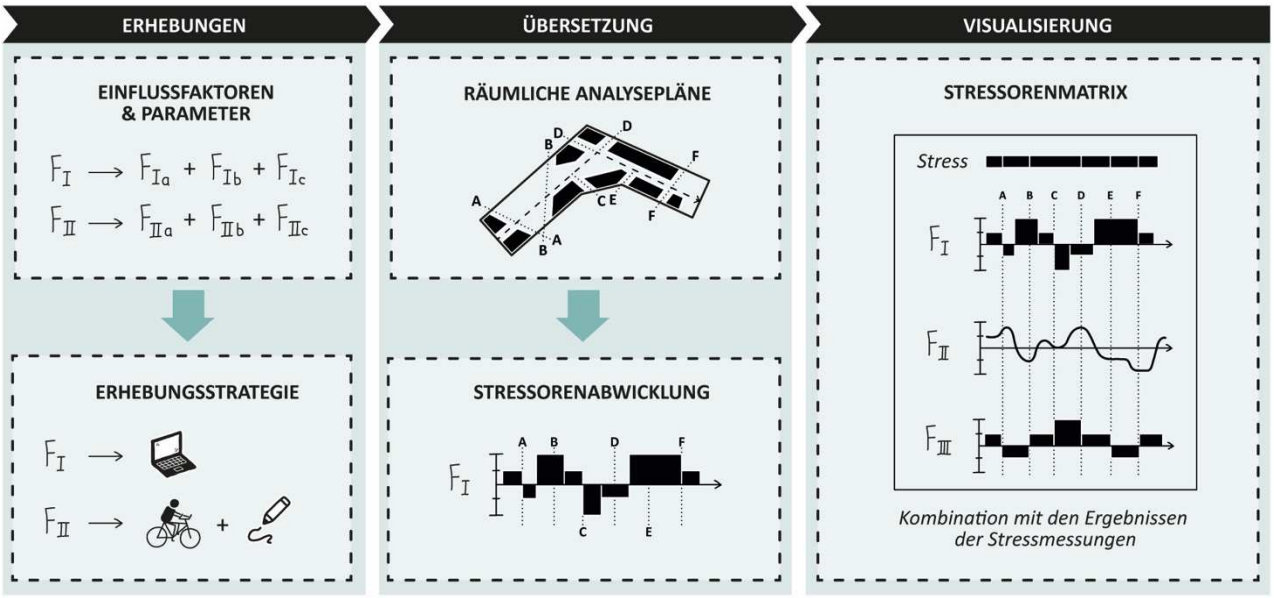

Abb. 6: Entwicklung der Methodenbausteine Stressorenabwicklung und Stressorenmatrix.

Durch die anschließende Gegenüberstellung der Stressorenabwicklungen in der „Stressorenmatrix“ und die Kombination mit den Ergebnissen der Stressmessungen (Abbildung 6, rechte Spalte) können dann die verschiedenen Zusammenhänge der Faktoren ausgewertet werden. Durch diese vergleichende Gegenüberstellung kann dabei gesichert werden, dass alle Faktoren aus den unterschiedlichen Themengebieten und Disziplinen dabei gleichwertig in die Auswertung einfließen können.

5 ERGEBNISSE

Im folgenden Abschnitt werden die Ergebnisse des interdisziplinären Stressforschungsansatzes behandelt, die aus den Erhebungen in den vier Fallstudien K1, K2, O1 und O2 entstanden sind.

5.1 Stressorenmatrizen

Abbildung 7 zeigt einen Auszug aus der Stressorenmatrix der Fallstudie K1 in der Untersuchungsstadt Karlsruhe. Von den 12 Untersuchungsfaktoren werden in dieser exemplarischen Übersicht die drei Faktoren „Verkehr“, „Erdgeschoss-Gestaltung“ und „Ruhender Verkehr“ gezeigt und gemäß der Methodik der

Stressorenmatrix mit den Ergebnissen der Stressmessungen in Beziehung gesetzt. Auffällige Stress-Hotspots zeichnen sich an der Kreuzung zur Karlstraße, sowie an der Einmündung zur Bürgerstraße ab.

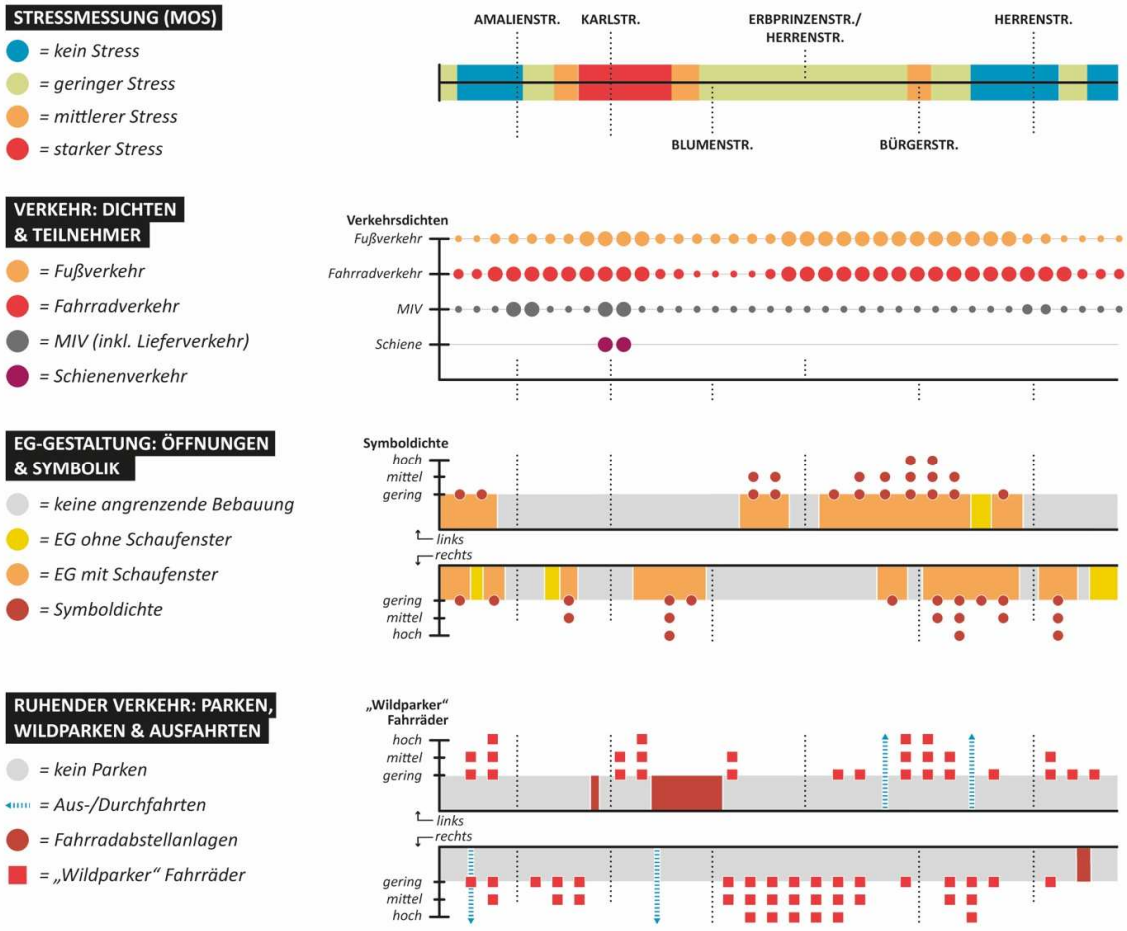

Abb. 7: Auszug aus der Stressorenmatrix Fallstudie K1: Vergleichende Darstellung der Stressmessungen mit den analysierten Faktoren Verkehr, EG-Gestaltung und Ruhender Verkehr.

In der Fallstudie K1 fällt hinsichtlich des Faktors „Verkehr“ auf, dass insbesondere an der Karsltraße ein erhöhtes Verkehrsaufkommen zu beobachten ist. Aber auch im Bereich der Bürgerstraße herrscht eine hohe Dichte des Rad- und Fußverkehrs. Die Erdgeschossgestaltung und Symbolik dieses Stadtraums konzentriert sich in diesem Kontext ebenfalls auf die vom Rad- und Fußverkehr stärker frequentierten Bereiche. In Bezug auf den Faktor „Ruhender Verkehr“ ist in K1 insbesondere das hohe Vorkommen von Fahrrad-Wildparken auffallend, das vorwiegend im Bereich von frequentierten Plätzen und Nutzungen stattfindet.

5.2 Auswertung

Abbildung 8 zeigt die Evaluation der Zusammenhänge der Untersuchungsfaktoren anhand der vier Stressorenmatrizen. In diesem Kontext wurde einerseits der Zusammenhang der Faktoren auf das Stressempfinden (links) und andererseits die gegenseitigen Wechselwirkungen der Faktoren (rechts) untersucht. Bei beiden Auswertungen wurde dabei nach dem gleichen Muster vorgegangen: Zunächst wurden hierfür in jeder Fallstudie jeder Faktor einzeln bewertet und dementsprechend die Werte 0 (kein Zusammenhang), 0,5 (partieller Zusammenhang) und 1 (starker Zusammenhang) zugeordnet. Für die anschließende Gesamtauswertung wurden dann die vier Einzelwerte aus K1, K2, O1 und O2 zu einer Gesamtsumme addiert. Daraus ergibt sich für den Gesamtzusammenhang eine Skala von 0 bis 4, wobei 0 für keinen Zusammenhang und 4 für einen sehr starken Zusammenhang steht.

5.2.1 Zusammenhang der Faktoren mit Stress

Im Rahmen der Auswertung ihres Stresszusammenhangs wurden die Stressorenabwicklungen der einzelnen Untersuchungsfaktoren in der Stressorenmatrix auf gemeinsame Hochpunkte und Auffälligkeiten mit der Abwicklung der Stressmessung untersucht und verglichen. Je nach Übereinstimmung der Hochpunkte

wurden dann die entsprechenden Werte für jede Fallstudie zugeordnet und zu einer Gesamtsumme addiert. Als Ergebnis kann schließlich der Faktor „Verkehr“ als ein Haupteinflussfaktor festgehalten werden, der in allen vier Fallstudien einen sehr starken Stresszusammenhang aufgeweist. Auch die Faktoren „EG-Gestaltung“, „Elemente“, „Straßenraum“, „Ruhender Verkehr“ und „Akustik“ können als Einflussfaktoren identifiziert werden, da sie insgesamt einen starken Zusammenhang mit Stress aufweisen.

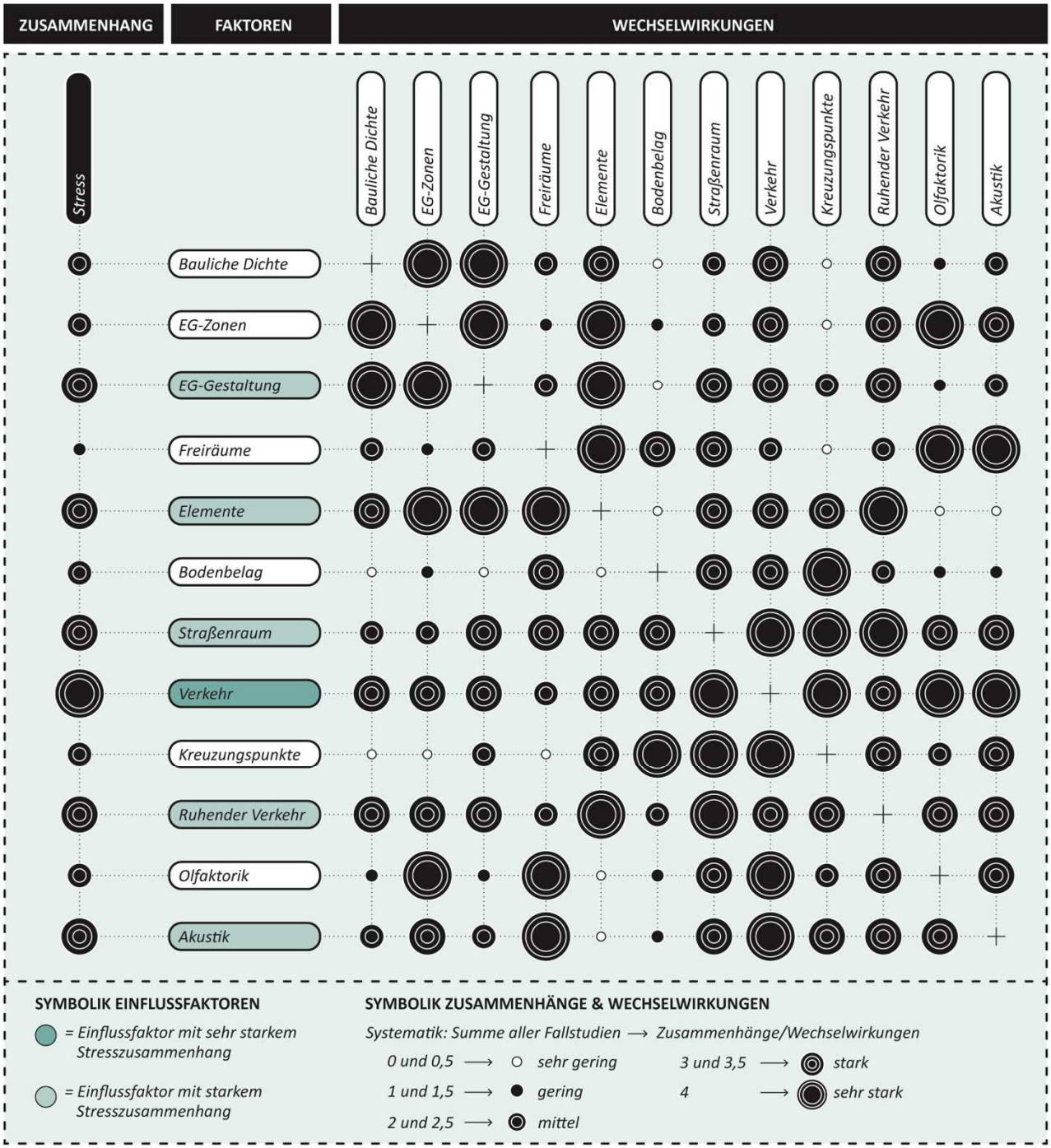

Abb. 8: Auswertung der Stresszusammenhänge und Wechselwirkungen der Untersuchungsfaktoren.

5.2.2 Wechselwirkungen der Faktoren und übergeordnete Stressphänomene im urbanen Kontext

In einem nächsten Schritt wurden dann nach dem gleichen Vorgehen die Wechselwirkungen zwischen den einzelnen Faktoren ausgewertet. Die einzelnen Zusammenhänge sind in Abbildung 8 dargestellt. Aus den identifizierten Wechselwirkungen lassen sich vier übergeordnete Phänomene im urbanen Kontext ableiten, die sich negativ auf das Stadterlebnis von Radfahrenden und Zufußgehenden auswirken:

(1) Überlagerung von Bewegungslinien: Bewegungslinien werden klassischerweise an Kreuzungspunkten und Einmündungen überlagert. In urbanen Räumen tritt dieser Effekt ab einer bestimmten Verkehrsdichte

jedoch auch auf, wenn verschiedene Verkehrsteilnehmerinnen und Verkehrsteilnehmer auf gemeinsam genutzten Verkehrsflächen gebündelt werden.

(2) Vermischung von Bewegungs- und Aufenthaltsbereichen: Tritt vor allem dann auf, wenn gemeinsam genutzte Verkehrsflächen durch Stadträume mit hoher Nutzungsdichte und Frequentierung hindurchführen. Dabei führen die verschiedenen Nutzungsmotive und Bewegungsmuster zu Konflikten.

(3) Verengung von Räumen: Klassischerweise bei Verengungen des Fahrbahnquerschnitts vorzufinden. In urbanen Stadträumen werden Engstellen jedoch insbesondere auch durch den Zusammenhang von Elementdichten und Wildparken, sowie der übermäßigen Ausdehnung von Erdgeschosszonen verursacht.

(4) Verortung starker Aufmerksamkeitsmagneten: Treten als „Kundenfänger" in urbanen Gebieten vor allem an hochfrequentierten Bereichen mit vielen Nutzungen auf. Sie führen nicht nur zu Ablenkung, sondern bergen auch durch das plötzliche Ändern der Bewegungslinie Konfliktpotential.

5.3 Ausblick

In einer nächsten Arbeitsphase setzt sich die Studie „Decoding Stress“ insbesondere mit der Anwendbarkeit des Methodenansatzes in der Praxis auseinander. Bis dato gestaltet sich die Anwendung der Methode noch sehr zeitintensiv. Im weiteren Verlauf soll deshalb der Frage nachgegangen werden, inwieweit die Erhebung der einzelnen Untersuchungsfaktoren, sowie die anschließende Übersetzung in die Stressorenabwicklung und -matrix zukünftig systematisiert und automatisiert werden könnte. Dabei sollen sowohl geoinformatische Ansätze, die sich mit der Automatisierten Auswertung von Luftbildern beschäftigen, als auch der Einsatz von Künstlicher Intelligenz im Rahmen der Analyse von Bildmaterial geprüft werden. Mithilfe dieser Automatisierung soll ein Technologiesprung forciert werden, der eine smarte, integrative Analyse und Planung von Mobilität und Stadt ermöglichen könnte. Damit könnte es perspektivisch gelingen, „stressige“ Stadträume erstmals auch ohne die Durchführung von Stressmessungen zu identifizieren, beziehungsweise deren Entstehung sogar komplett vorhersehen und dementsprechend vermeiden zu können. Die gewonnenen Erkenntnisse können damit zukünftig einen erheblichen Beitrag dazu leisten, Lösungsansätze für die Gestaltung qualitätsvoller und menschengerechter öffentlicher Stadträume zu erarbeiten.

6 DISKUSSION

Die Auswertung der vier Fallstudien liefert im Sinne der Ursachenforschung des Stressempfindens von Radfahrenden und Zufußgehenden im urbanen Kontext erste inhaltliche Erkenntnisse hinsichtlich relevanter Einflussfaktoren in den untersuchten Fallstudien. Es bleibt jedoch zu evaluieren, wie es sich mit deren Gültigkeit verhält, wenn die Stichprobenzahl erweitert wird. Als Anknüpfung an die Untersuchungen der Studie „Decoding Stress“ erscheint es zum jetzigen Zeitpunkt daher sinnvoll, Anschlussuntersuchungen mit weiteren Fallstudien in anderen urbanen Gebieten durchzuführen, um die Ergebnisse weiter zu überprüfen.

Mit der Studie „Decoding Stress“ wurde eine Methodik entwickelt, die es ermöglicht, nicht nur „harte“ Faktoren in der Stressorenanalyse zu berücksichtigen, sondern erstmals auch Aspekte der Stadt- und Raumwahrnehmung miteinzubeziehen. Damit wird ein Beitrag dazu geleistet, das subjektive Empfinden des Menschen bei seiner Bewegung durch die Stadt zu erforschen und ihn erstmals auch in den Fokus der Stressorenanalyse zu rücken. Aus diesem Verständnis heraus bleibt das Subjekt, also der seine Umgebung wahrnehmende Mensch, ein wichtiger Teil der Methodik. Es ist ihr Anspruch, unsere subjektive Raumwahrnehmung zu erfassen, ohne dabei jedoch die subjektive Komponente vollständig zu eliminieren. Die in den Stressorenabwicklungen analysierten Faktoren können deshalb nicht als vollumfänglich objektiv angesehen werden, sondern stellen vielmehr ein Zusammenspiel dieser beiden Dimensionen dar.

Hinsichtlich der angestrebten Automatisierung der Methodik bleibt es vor allem auch in diesem Kontext zu diskutieren, inwieweit Künstliche Intelligenz zukünftig im Stande sein wird, die menschliche Wahrnehmung nachzuempfinden. Für einige der hier untersuchten Parameter, wie zum Beispiel der Wahrnehmung von Frequentierungen, bietet die Anwendung von KI-Systemen bereits heute durch die Festlegung eines Regelwerks bereits adäquate Lösungsansätze. Es wird jedoch zu klären bleiben, inwieweit vor allem die subjektive Bewertung von sensuellen Faktoren, wie zum Beispiel Gerüchen oder Geräuschen überhaupt von Künstlicher Intelligenz abgebildet werden kann, da diese Faktoren überwiegend von persönlichen Erfahrungen und Suggestionen beeinflusst werden.

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🏆 *reviewed paper*

Developing a Technological Innovations Framework for Energy Security: a Case of City Power, Johannesburg

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1 ABSTRACT

Rapid urban growth in the world's cities, particularly in the Global South has placed unprecedented demand for energy supply that keeps vital urban energy systems functioning in order to support life and economic activities in urban areas. Cities are the net consumers of energy (electricity) and other life-supporting services, as a result they require proper planning and coordination to ensure the resilience and energy security of urban areas. South African Cities, have consistently been experiencing energy shortages through rolling blackouts that date back to 2008.The study aims to develop a holistic framework that informs appropriate innovations that enable the achievement of energy security at City Power in the City of Johannesburg. The work adopted a mixed methods approach that uses both quantitative and qualitative data. Specifically, data was collected through interviews, surveys and observations; reviews of published journals, journals reports and government policy documents. Descriptive statistics, content analysis, narrative analysis, and discourse analysis were used to sieve information from the data. The research findings reveal that residents of the City of Johannesburg are only able to access electricity for an average between 7-12 hours in a day due to energy shortages. The city of Johannesburg is experiencing vulnerability of energy systems in the form of energy blackouts as the result of energy power cuts at the City of Johannesburg. The work posits that, through an energy planning model, the City of Johannesburg, through its power utility City Power could plan for the mitigation of energy black outs through implementation of microgrid planning. Consequently, the study recommends that the City of Johannesburg follows the existing legal frameworks and other planning laws that are available to develop spatial plans for infrastructure development for renewable energy within its area of jurisdiction. The framework for sustainable energy (electricity) security in the City is developed by combining technological innovations with spatial planning.

Keywords: energy security, energy planning, spatial planning, cities, urban growth

2 INTRODUCTION

Rapid urban expansion in the world's cities is placing unprecedented demands on multiple life-supporting services like energy (Sperling & Burke, 2017). Whereby cities are the net consumers of energy and other life-supporting services, and that as a result requires coordination that takes into account urban systems that are critical to the future well-being of communities and ensures the resilience of urban areas. The first industrial revolution was a result of efficient energy consumption that was used to support the explosion of population growth during the 1700s in European cities. The cycle continues three centuries later, during the present era of the fourth industrial revolution, due to the absolute dependency on energy of contemporary society. The present and future of society are dependent on the ability of cities to have energy security.

The idea of energy security in the Republic of South Africa has been one of the issues facing the country, evident through power cuts that have lingered for 15 years and counting. South Africa has been experiencing a series of power cuts since 2008 due to the state-owned electricity utility Eskom's insufficient power generation capacity (Shapely & InglesiLotz, 2022:1). The existence of modern society is dependent on energy (electricity), whereby towns, rural areas, and cities require some sort of energy to enable communities to function across the full spectrum of various endeavours.

Energy security concerns are aligned with United Nations Sustainable Development goals with specific focus on Goal 7 (Affordable Clean Energy).The goal of affordable clean energy is interlinked with other Sustainable Development Goals as stated in the United Nations policy brief as it outlines the linkage between SDG 7 with other linkages namely: linkage between energy and education (SDG 4) "Energy is critical in ensuring schoolchildren's access to educational services such as information and communication technology

(ICTs).” (UN Policy Briefs, 2022: 12) , linkage between energy and Gender equality (SDG 5) is due to “Due to their gender roles and responsibilities, women are disproportionately affected by unequal energy access, and creating an enabling environment for women's participation in the energy sector includes gender responsiveness in energy planning, legislation, and regulation ” (UN Policy Briefs 2022: 37), and Linkage between energy and sustainable land use (SDG 15) “Renewable Energy land system interlinkages have four dimensions: sustainable natural resource management, efficient use of land and biomass resources, appropriate land system governance, and implications on land users' well-being ” (UN Policy Briefs , 2022: 47).

The question of energy security in South Africa has not received the attention that will bring about a sense of urgency; hence, energy issues have lingered for almost two decades. Apart from the intent by the state to provide a policy framework through the National Development Plan, according to the fourth chapter of the National Development Plan, "South Africa needs to maintain and expand its electricity, water, transport, and telecommunications infrastructure in order to support economic growth and social development goals" (NDP, 2030:163), Such acknowledgment was formally made in 2013 when the policy framework was made official; however, the expansion of energy generation has not materialized. The purpose of the study is to develop framework (Localised Energy Planning Model) for technological innovations for energy security in the City of Johannesburg.

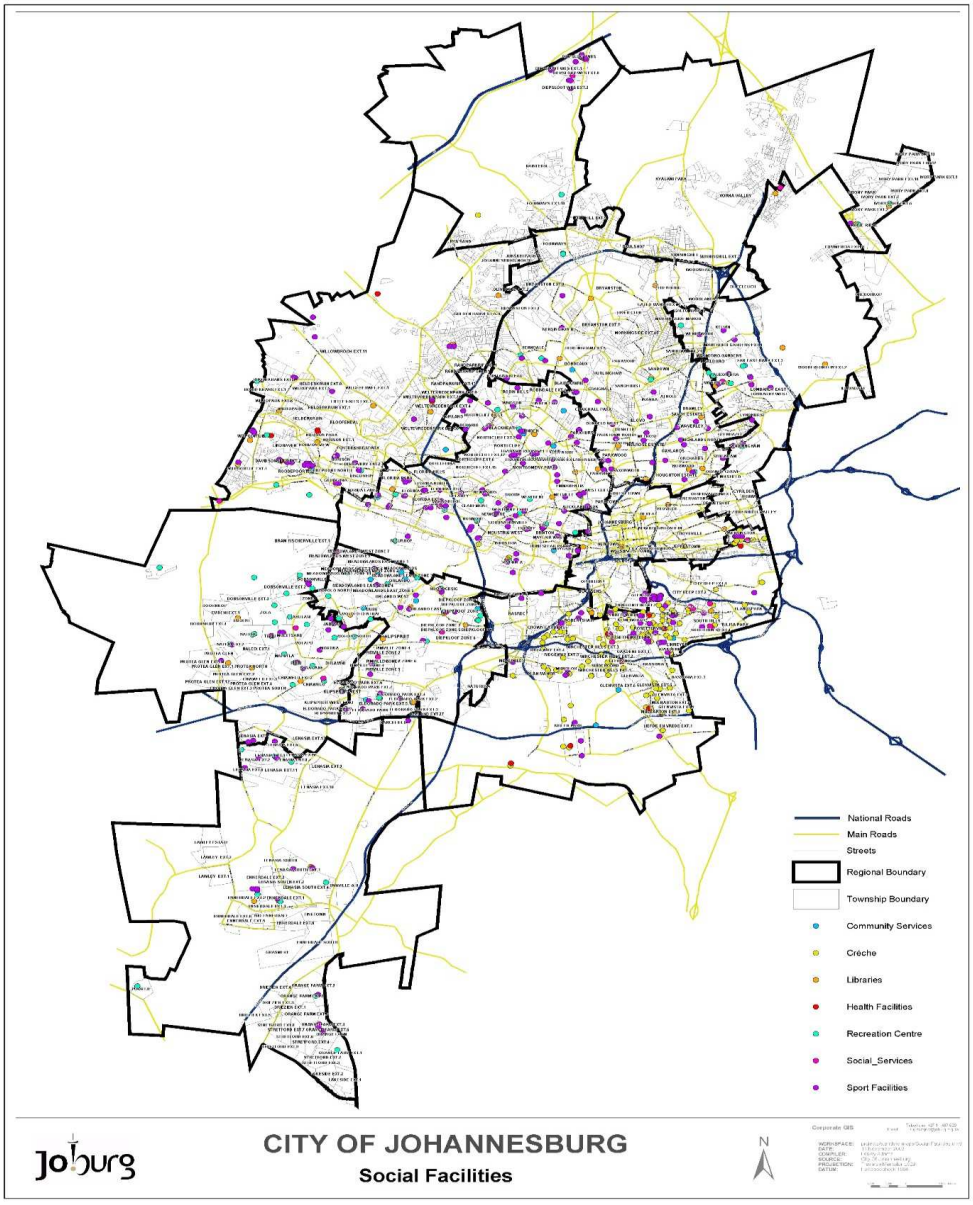
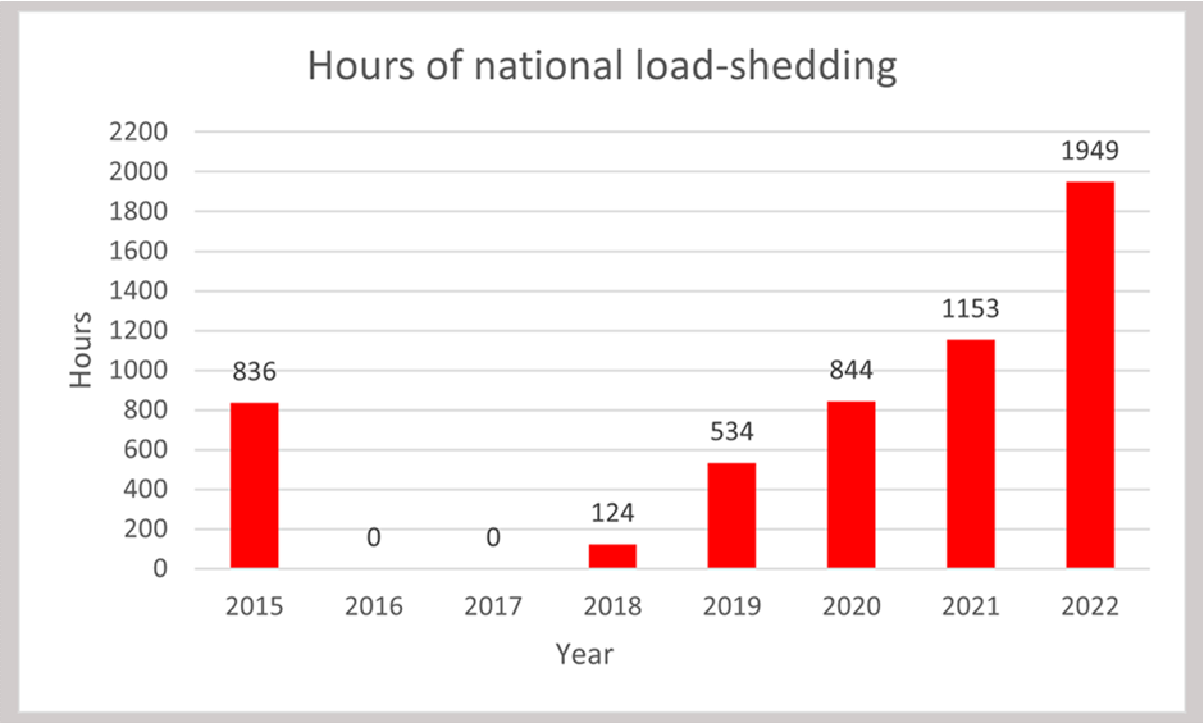


Figure 2.1.1: City of Johannesburg Power Grid (Source: City Power Integrated Report 2021). (Source: City Power Integrated Report 2021)

3 BACKGROUND

Secondary data is the data that has already been collected through primary sources by other parties and made readily available for other researchers to use their own respective research projects. In the context of the current study as it is about studying energy security in the City of Johannesburg. It is important to give a background information about the source of electricity, in terms where does it comes from before spatial entity called City of Johannesburg could consume it for various purposes by all who live in the city. To present evidence about the energy security it is important to take into account the steps that precede the distribution of electricity in South Africa. Due to system of governance in the republic of South Africa that is made up of three branches of the state which are namely: National Government, Provincial Government and Local government, in this case the major source of electricity comes from the state-owned entity that operates to the national level. The entity is responsible for generating electricity from the national level through its network of power plants that are distributed in all nine provinces of South Africa. According to the Eskom's Integrated Results (2019), the total nominal capacity as of March 2019 amounted to 45GW.City of Johannesburg is situated in the Gauteng province and the city has its own electricity distribution network which is shown in figure 6.3.1. The network of the City of Johannesburg carries 12GW of electricity that runs the city and keeps urban energy systems running as well as the city functional according to City Power's report of 2021.The figure below shows the map of electricity distribution of the City of Johannesburg.

The comparison of the total energy capacity of the country compared to the one of the City of Johannesburg indicates that almost 25% of the national grid energy is consumed by the City of Johannesburg when it comes to ratio. The City of Johannesburg metropolitan municipality with its population size is bigger than other nation states in the globe and also in the African continent, whereby that alone creates a need for the city to place a strong emphasis on energy planning in light of the new policies that have been signed into law by the National government of South Africa that allows local governments to have their own generating capacities. Whereby the generating capacity begins with planning that is informed by sufficient data that put all the material factors into the table that shape the dynamic of the City. One of these dynamics is the demographic growth of the City of Johannesburg. The hypothesis of the study is that "as population of the spatial entity continues to growth, that puts pressure on the current energy capacity that needs to plan for future needs."



(EskomSePush, 2023).

There are numerous studies that have been attempted to uncover energy planning and security in the developing world in the global South. Where these studies have been conducted with an objective of

understanding the extent of energy security in developing nations including African continent. The current study focuses on the local government context regarding the energy security and subsequent development of technological innovations that are aimed towards improving the stable access to electricity in the City of Johannesburg. From the basis of that information the data will demonstrate the actual issue that are facing the City of Johannesburg when it comes to factors that contribute to energy security in the city, one of the issues among these are disruptions that are caused by power outages at the demand for energy outstrips the supply. At the core of energy security affecting the City of Johannesburg are power outages or energy blackouts that are known as load shedding, this is the phenomenon that has characterised South Africa. The figure 2.1.2 shows the number of load-shedding hours each year from 2015 to date, sourced from (EskomSePush, 2023).

4 CONCEPTUAL SYNOPSIS

One of the objectives of the new democratic dispensation in the republic of South Africa after 1994 was to transform spatial partners that were informed by the past spatial planning. There were various measures that were taken by the state in the interim like, which was the part of the freedom of movement in the country to live in cities because of pull factors in the urban areas. It was until 2013 where the law that governs the overall land use in all spheres of the government namely (a) Local government, (b) Provincial government and (c) National government. The passing of the Spatial Planning and Land Use Management Act 16 of 2013, did set up a legal framework that will guide spatial planning in the republic. Spatial transformation is informed by Spatial Development Frameworks (SDF) whereby according to section 12 subsection (1) of the SPLUMA Act states that “12. (1) The national and provincial spheres of government and each municipality must prepare spatial development frameworks that (a) interpret and represent the spatial development vision of the responsible sphere of government and competent authority; (b) are informed by a long-term spatial development vision statement and plan;(c) represent the integration 32 32 and trade-off of all relevant sector policies and plans;” (South Africa, 2013:21) .Spatial transformation follows the guide lines of the spatial development frameworks that are aligned from across all spheres of government, spatial transformation is a part of strategic spatial planning. Strategic spatial planning in the post-apartheid era has attempted to promote more compact and integrated cities, and to redress patterns of inequality of the past (Todes, 2012). One of the objectives of strategic spatial planning in the post-apartheid South Africa was and still is the spatial transformation of planning patterns of the past. There have been various reforms on the policies by South Africa government on energy security from 1994.Energy policy frameworks were aimed at improving energy security based on the expected economic growth and expansion of service deliver to previously disadvantaged groups. There are four key policy frameworks to be discussed namely: National Development Plan, Integrated Resource Plan, National Electricity Act 34 of 2008 and the amendment of National Electricity Act.

4.1 National Development Plan 2030

The National Development Plan is one of the unique policy frameworks as it attention not only focuses on the domestic affairs of South Africa, instead the policy looks at the orientation of South Africa as global player in the rest of the world as the phenomenon of globalization takes place in the wake of global economic recession of 2008.From that standpoint, there was an understanding that International and regional developments affect the republic of South Africa in multifaceted ways. Due to positive implications of globalization for South Africa’s development, notwithstanding several notable risks (NDP, 2030:30).One of the key objectives of the National Development Plan is to “ to invest in a strong network of economic infrastructure designed to support the country's medium- and long-term economic and social objectives” Through “maintenance and expansion of electricity, water, transport and telecommunications infrastructure in order to support economic growth and social development goals” (NDP, 2030:158).These policy objectives are meant to increase the capacity of South African Infrastructure in terms of its ability to support economic growth , where the key infrastructure items that is constantly being highlighted in these policy frameworks is the issue of energy security.

4.2 Integrated Resource Plan

Electricity demand trends in South Africa as projected in the period between 2010 and 2030 continues to be visible with the current more supply of energy that continues to fall under strain due to constant power cuts

taking place in the South African energy grid. Ateba, (2019) attributes the South Africa's industrial decline and dwindling economic growth prospects are directly associated with decreasing electricity poor accessibility, as the industrial sector is the main economic contributor to South Africa's GDP. Much of the issues that are affecting the aggregated economic prospects of the country includes the insufficient supply of energy that is necessary to support economic growth of South Africa. One of the issues that were accentuated by integrated resource plan was the issue of increasing the available supply of electricity by to ensure the equilibrium between the available energy supply and the demand of for electricity in South Africa. The emergence of integrated resource plan (IRP) came as the electricity capacity plan which a sole objective to provide an indication of the country's electricity demand, how this demand will be supplied and what it will cost (Govender and Dempster, 2019).Over time between the promulgation of the policy back in 2019 up to today, South Africa has suffered worst energy blackouts in its history as the country has endured almost 100 consecutive days of load-shedding between October 2022 and the 6th of February 2023 (Naidoo, 2023).The efficacy of the Integrated Resource Plan according to the studies that have been published and reports that emerges seems to paint a picture that is completely different from the original intent of the policy to guide the measures to energy security.

4.3 The National Electricity Act 34 of 2008

The formulation of the Act was an attempt to bridge the gap between, fragmented development of energy laws in the new South Africa and regulation on the one hand and environmental law on the other is influencing against the adoption of a sustainable energy system in South Africa (Murombo, 2015).One of the key objectives of the act is to ensure that diverse energy resources are available to bring about the sustainable energy mix in South Africa, through quantities that are both sustainable quantities and at affordable .The objective is aligned with the wide definition of energy security that revolves around 4As which are namely: physical availability; economic affordability; accessibility from a socio-political standpoint; and environmental acceptability (Fang, 2018).One of the key aspects of the act is to " to provide for energy planning, increased generation and consumption of renewable energies", as the study seeks to examine energy security from planning standpoint within the local government context.

4.4 The amendment of National Electricity Act 34 of 2008

The amendment of the National Electricity Act 34 of 2008 represented a major shift in the energy planning ethos of the local government, meaning that the local governments are provided an opportunity under law to participate in the energy generation initiatives within the areas that fall within their jurisdiction. Under chapter 5 Section (4) states that "Regulation 5 of the Regulations is hereby amended by the addition of the following sub regulation: "(3) A municipality. As an organ of state, may apply to the Minister to procure or buy new generation capacity in accordance with the Integrated Resource Plan. The amendment represents the alignment between the objectives of the National government and local government to pursue energy self-sufficiency. The act was amendment in the year 2020 to accommodate municipalities with the provision in the law. Thus, creating the grounds for the study to be conducted that will enable energy planning that will address energy security concerns in the City of Johannesburg. The amendment represents the current state of the situation in terms of major regulations that are governing electricity in South Africa.

5 RESEARCH METHODS

5.1 Research Design

The case study design was adopted for the research as it is profoundly relevant in offering a targeted and in-depth exploration of the intricacies and challenges within a specific context of the city. By focusing on City Power in Johannesburg, the case study provides a nuanced understanding of the local dynamics, regulatory frameworks, and collaborative efforts in the pursuit of energy security. This approach allows for a detailed examination of the practical implications of technological innovations within the unique urban landscape of Johannesburg. The case study design enables the identification of context-specific barriers and opportunities, fostering a more comprehensive and tailored framework for advancing energy security through technological innovations. Moreover, the insights garnered from this case study are not only valuable for City Power, but also serve as a rich source of lessons and recommendations with broader applicability for other urban energy contexts, contributing to the advancement of sustainable energy practices on a larger scale. 20

5.2 Research approach

The research adopted a mixed-methods approach as the methodology was deemed highly relevant due to the multifaceted nature of the established research questions. By combining both qualitative and quantitative methods, this approach provided a comprehensive lens through which to examine the complex interplay of technological innovations and energy security in a real-world urban setting. The qualitative element of the work allowed for an in-depth exploration of contextual nuances, capturing the perspectives of key stakeholders, and elucidating the intricate dynamics within City Power. On the other hand, the quantitative element assisted with facilitating the gathering of empirical data from the respondents, thus enabling the measurement of the impact of technological innovations on energy security metrics. The mixed methods approach not only enhanced the robustness of the study, but also ensured a more holistic understanding of the factors influencing the success of the proposed framework. The approach enables the synthesis of qualitative insights with quantitative data to produce a well-rounded examination of the critical issues surrounding technological innovations for energy security in the specific case of City Power, Johannesburg.

The purpose of data analysis is to establish meaningful insights from raw data that has been collected with an objective of answering research questions as outlined as goals and objectives of the study, identify patterns that are reoccurring, and extract valuable information that will be useful to answering the questions. Since the study is a mixed methodology study, it has got both numerical and non-numerical data that has been obtained from the survey of participant that were sampled in the study. The study has three parts namely: (a) Demographic profile, (b) Public sentiment around energy security, and (c) Public opinion on possible solution for possible solutions for energy black outs.

6 RESULTS AND DISCUSSION

6.1 Demographic profile of participants

The 21st century is currently undergoing a significant majority of the world's population preferring to living in urban centres (Katleni et al.,2016). The City of Johannesburg with its large population is one of the major contributors to the Gauteng and South African economy, and its economic growth rate is larger than the national and provincial levels of government (Karuaihe, 2013). The city of Johannesburg offers insights with its demographic profile into urban governance and the interesting interaction between managing the demands for infrastructure in a rapidly urbanizing context of the spatial entity (Abrahams & Everatt, 2019). The city has the diverse population groups with different levels of social status and different participation levels on the economy. Demographic profile of the sample area shows the composition of participants that took part in the study, it is broken down into five key categories namely: economic status, citizenship, gender, marital status, and number of people in the household.

Economic status

The composition of participants that were sampled are 32% Self-employed, 32% employed, 14% unemployed and looking for employment, 12% not employed and not looking for employment and 10% was a subset of participants who indicated that they are still busy with their studies to get skills at different training institutions. The informal sector is distinguishing feature of emerging and developing economies, particularly in Africa and Latin America (Bargain and Kwenda, 2011). The inner city of the City of Johannesburg has huge number of people that are small business owners (Zulu,2020) that are self-employed, and another percentage is for people who are employed and working for someone else in different industries within the City of Johannesburg, followed by 10% of student population as the city has many training institutions for different skills. The massive growth of private student housing across cities globally including the developing world, and much of this has been attributed to the increased neo liberalisation and mainstreaming of higher education (Gregory & Rogerson, 2019) and other group is for people who are unemployed made up of those who are looking for work on the active basis and those that have given up on finding work opportunities. The high levels of unemployment in South Africa are a key concern for young people after leaving school. (Graham and Mlatsheni, 2015). Unemployment is responsible for increase in urban poverty in the post-apartheid period (Crankshaw, 2022).

6.2 Citizenship

The City of Johannesburg is made up of different nationalities within the City of Johannesburg as the city is understood as the cultural melting pot, (Harrison & Zack, 2012) meaning that the city is made up of different nationalities, whereby according to the surgery it shows the 66.7% majority by South Africans and 33.3% foreign nationals from the sample that was willing to participate voluntarily in the study. Earlier, in 2015, the United Nations had already projected out that population growth in the 21st century will be concentrated mainly in African continent (UN-DESA, 2015). Africa is experiencing unprecedented urban growth (Totafori, 2020).

6.3 Sex

Show the gender composition of the participants that is broken down between males and females, whereby males make up the majority of the participants with 58% and 42% females that took part in the survey.

6.4 Marital Status

This part refers to social composition of the participants, whereby singles make up the majority of the population by 64% followed by 34% and 2% of divorced. The data point helps to identify the family composition of participants who took part in the study.

6.5 Number of people in the household

Refers to the number of people within the household where each participant resides composition of the participants, whereby households with people from 2-5 represents the high number of households within the sample, followed by households with those households with 6-10 people within the households and these living alone.

6.6 Public sentiment around energy security

One of the strong sentiments that have been highlighted by the participants of the study with regards to energy security is the response around the number of hours in a day community have been without electricity is the financial implications of energy security that are high cost of living and high input cost of doing business. The data further suggest that in the year 2022 an equivalent of 82 days was lost due to power cuts as the result of energy blackouts as national energy grin was unable to sustain the supply of energy. The power cuts are also being experienced by the City of Johannesburg since it also gets electricity from state owned power utility ESKOM. The survey revealed that the communities are able to access electricity from 7-12 hours in a day by vast majority of households. And the mean or average number of days in which households without electricity is 6.97 days, meaning that there is a slow response in resolving electricity related disruptions that take place outside black outs alone. That on its own indicated the vulnerability of vital energy systems of the city in terms of unstable electricity grid.

6.7 Discussion

The use of solar energy and other renewable energy solutions has been suggested by communities as the initiatives that the City of Johannesburg could embark upon to stabilise the local energy grid of the municipality. Followed by the provision of free basic electricity for poorer households that are struggling to keep up with the steep electricity prices. There are deep concerns about the affordability of electricity in the future as the prices continue to climb. And the issue of vandalism has been highlighted as major concerns among communities that participated in the survey, meaning that some of the vulnerabilities in the energy systems are due to vandalism of the infrastructure.

According to the data it implies that entire country has experienced load shedding or energy blackouts for almost 2000 hours in 2022 meaning that if we divide number of our by a day which is made up of 24 hours we have = 1949 hours X (Day/24 hours) = 81 days in 2022 were equivalent to total darkness, 48 days in 2021, 35 days in 2020, 22 days in 2019.This means that out of 365 days a year the City of Johannesburg experienced an equivalent of 81 days of total darkness without any electricity. In light if the current situation with regards to energy security in the City of Johannesburg that continues to grow quite significantly in terms of population the current capacity will not be enough to satisfy the demand that comes with urban future growth. According to WorldData (2023) the South African electrical energy consumption per capita is at an average of 3.377kWh, from this information this means that in proportion to population growth of the

country as recoded from decade to decade the energy needs continue to grow. The specific reference to this growth phenomenon of population in the local government of the City of Johannesburg grew from 4.2 million in 2011 to 6.2 million people in 2022 which is information taken from Statistics South Africa from census data. This means that in the light of energy shortages that are currently being experienced by the city there has been and addition of 2 million people who need an average of 3.377kWh of energy on the daily basis. The table below shows the electrical energy consumption per capita of South Africa in comparison with USA (Data sourced from WorldData, 2023).

5.8.1. Energy consumption comparison Republic of South Africa compared to United States of America

Electricity	Total	South African electricity consumption per capita	USA electricity consumption per capita
Own consumption	202.29 bn kWh	3377.4 kWh	11695.27 kWh
Production	231.85 bn kWh	3870.99 kWh	12147.64 kWh
Import	7.82 bn kWh	130.61 kWh	184.37 kWh
Export	14.48 bn kWh	241.79 kWh	42.41 kWh

Source: (WorldData, 2023)

Emanating from the two data points from figure 6.3.1 and 6.3.2 it is evident that the ability of the City of Johannesburg to have energy security for the area that fall under its jurisdiction is a concern that needs to be addressed. As the city is currently being affected by external factors that directly affects how the city functions on being the phenomenon of population growth and the other variables being its dependency upon the capacity of the state-owned entity for its electricity. In this section we shall be presenting data points from other studies with specific focus on energy security and technological innovations in the urban context. This data will be presented in the form of codes that will be highlighted as key themes of the secondary data presentation namely: Technological innovations and energy security, Urbanisation rate and energy security, Industrialisation rate and energy security, Population growth and energy, Energy consumption security, Financial Development and energy security, Spatial trade-offs and energy security

6.7.1 Energy consumption security

Following the global pandemic in the year 2020 and 2021 that was followed by the return to normal business activities that require the use of electricity to boots strong economic recovery drive a rapid rebound in energy demand. Those energy demands raised concerns about energy security in the globe (Wang and Lee, 2020).With varying degrees of energy supply and demand all over the world as cities where beginning to return back to normal functioning this saw a shift on supply chain of energy products (EU Report, 2021).In the column released by Reuters (2021) “Worldwide energy shortage shows up in surging coal, gas and oil prices” according the publication prices for commodities began to climb as the world economy was beginning to open up and that directly raise concerns about energy security for cities that is being affected by global commodities markets. The figure 6.3.2.1 below shows the timeline for energy prices from year 2020 to 2021.

6.7.2 Technological innovation and energy security

The fourth industrial revolution has brought about an era known as Industry 4.0, and to keep up with this structural economic shift towards digitisation of various aspects of society through technological innovation, the role of innovation is being reinterpreted as a catalyst for digital transformation (Chen et al., 2021).These innovations have an effect in energy systems that are responsible for functioning of contemporary society through improvement that is driven by extensive knowledge of how systems work over the years. Improvements in energy use cannot be achieved without technological advances (Rip & Kemp, 1998). Technological Innovations bring about efficiency in the production and use of energy in general and its responsible for newer and greener modes of electricity generation and improving energy security overall through monitoring of the grid capacity (Rüßmann et al.,2015). With an intention of driving global development that sustainable, technological innovations have a significant role to play in improving how global cities consume energy. Technological advancement and development are regarded as the most significant and practical technique to increase energy consumption efficiency, storage efficiency and generation from sustainable sources that are renewable (Rae, 2012).

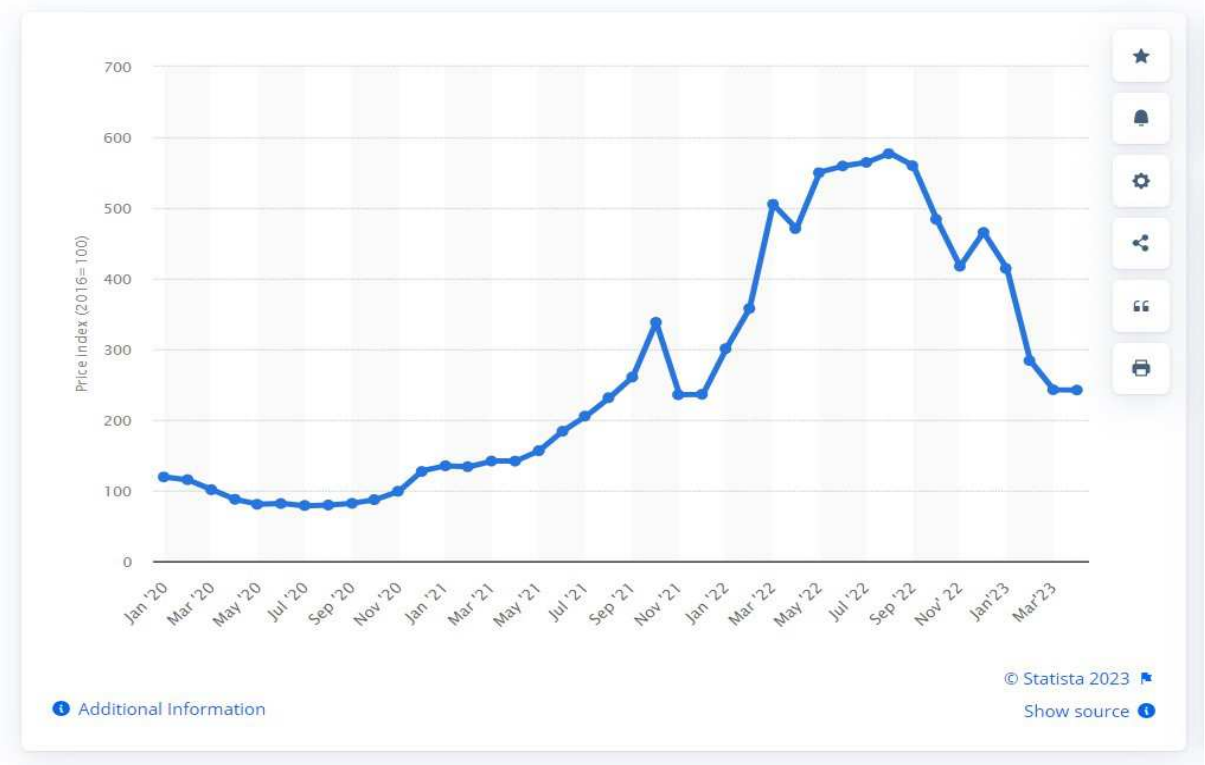


Figure 2.7.3 Coal Prices. Source: (EU Report, 2021)

6.7.3 Spatial Trade-offs and energy security

To achieve long-term carbon emission reduction targets, land-based, utility-scale renewable energy systems that generate power from solar or wind resources are emerging as a clear choice. Local governments are responding in kind by setting their own objectives and/or rules to help renewable installations succeed in their areas of responsibility (Guo et al., 2020).Against the of the demand for energy and related services grows to meet social and economic growth, anthropogenic greenhouse gas (GHG) emissions and the resulting atmospheric concentration have reached a historical high relative to pre-industrial levels (Change, 2014).The demand for land use in the urban areas like in the City of Johannesburg where there is a massive population growth due to urbanisation, massive demand for energy (electricity) that is necessary to urban systems and vital services of the city. This will create a competition between various land use requirements due to competing land use interest of the city. However, the need for the city to mitigate against the negative impact of energy blackouts to stable local electricity grid, the spatial trade-offs is one of the feasible solutions for the city to allocate land that would be dedicated for renewable energy and other technologies for stabilising the local grid of the City of Johannesburg municipality.

7 CONCLUSIONS AND RECOMMENDATIONS

The study has found that the city of Johannesburg is experiencing vulnerability of energy systems in the form of energy blackouts as the result of energy power cuts that have engulfed the entire country South Africa. In the year 2022, the country lost an equivalent of about 82 days without electricity as a result of energy blackouts. The study has discovered that through energy planning model for the City of Johannesburg, the city through its power utility City power could plan for mitigation of energy black outs through the implementation of microgrid planning to utilize technological innovations for energy storage sites to ensure that there is minimized number of hours parts of the city without energy. The role of technology in intervening in energy security would be to provide data centres that would be responsible for monitoring the capacity of the electricity grid in all 135 wards for the city of Johannesburg. The data from the database can be potentially useful in quantifying peak periods for electricity demand in each ward, and this was useful in determining the battery storage sites that could be appropriate for each site. The study suggests that through urban planning, the control of land use 89 is the foundation to strategically develop the technological infrastructure that supports energy systems of the City of Johannesburg with an aim of securing stable energy supply. Based upon the study conducted, this section outlines the recommendations that can be adopted by

the City of Johannesburg in terms of energy planning strategies that aimed at protecting the local electricity of the of the city grid from energy blackouts. By following the existing legal framework and other legislative mechanisms that are available to enable local governments to develop spatial plans that will enable the infrastructure development for renewable energy within the area that fall under the jurisdiction of the municipality.

The integration of energy planning into the scope of mainstream planning. The integration of energy planning into IDP (Integrated Development Planning) programmes of the municipality, the inclusion of energy planning into spatial planning by creating the spatial development frameworks that will designate certain land portions to support local energy grid.

Urban growth monitoring measures, by limiting low density developments. The pursuit of energy security in the city requires land resources in the same way the urban expansion does require land. In this way the municipality could avoid urban expansion by low density neighbourhoods as that will take up more land that could have been used for other purposes like grid scale technology and wind power sites.

Categorisation of vital energy systems that needs to be prioritized first, in order to inform the energy planning priorities that need to be attended first, due to limited resources when it comes to capital expenditure allocated to various infrastructure initiatives.

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Development of an Energy Transition Cycle in the City of Eisenstadt

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1 ABSTRACT

In course of the project “Creative Circle” a so called “energy transition cycle” in Eisenstadt is developed. This energy transition cycle aims to support the efficient use of the local renewable energy production. In addition, climate change adoption measures are implemented.

The local district heating network, the sewage treatment plant and photovoltaic systems form the basis of the project. A large part of the population is currently supplied with heat from the district heating network that is mainly heated with biomass. Currently, a part of the heat goes unused with the wastewater to the sewage treatment plant. This is set to change in the future. The thermal energy in the wastewater will be integrated into the district heating network by using a heat pump. With regards to the electricity supply, a renewable energy community was established. The electricity demand of the heat pump as well as the electrical demand of the inhabitants of Eisenstadt can be partly covered with renewable energy from the energy community, at favorable tariffs. The energy from the energy transition cycle is also used for the environmentally friendly operation of a multifunctional Cooling Center, which provides a cool place to shelter from extreme heat free of charge and also functions as a social meeting point. As first part of the energy transition cycle, the Cooling Center located in the town house of Eisenstadt was completed in summer 2023. The foyer in the town hall was redesigned to make the stay as pleasant as possible and an innovative cooling system was implemented. The planning of the wastewater heat utilization at the sewage treatment plant was carried out in parallel. The integration of a heat pump in the sewage treatment plant shows considerable potential for reducing biomass and gas consumption and increasing the efficiency of the district heating network. However, the implementation of the project is not without its challenges. The technical design of the heat pump integration requires careful planning and coordination with the existing systems. Choosing the right size of heat pump, taking the biomass system into account, and increasing efficiency are complex tasks that need to be tackled carefully. Detailed planning and economic evaluations are currently being carried out.

Keywords: waste water heat pump, cooling centre, enery transition cycle, energy community, participation

2 INTRODUCTION

To prevent a further progress of the climate change and to achieve the European as well as the national climate targets, comprehensive measures are needed, which include an increasing share of renewable energy sources in the energy supply. In addition to that, cities in particular are already strongly effected by summer overheating. The number of hot days (days over 30°C) has doubled to tripled in Austria in recent decades [GeoSphere Austria, 2022]. Thus, climate change adaptation measures are also needed, which should take place in addition or complementary to climate protection, as the inertia of the climate system means that climate change will continue to progress even if we reduce emissions. The aim of climate change adaptation is therefore to react proactively to future climate change and to take measures to avoid future damage and take advantage of opportunities that may arise.

On behalf of the Austrian government and the federal provinces, climate scenarios for Austria have been created on the basis of global climate models in order to have a reliable, high-quality and application-oriented basis for dealing efficiently with the challenges of climate change at the level of the federal provinces. These scenarios allow the following key statements to be made for Burgenland, the federal state in which Eisenstadt is located [Novakovits, 2020]:

- Mean annual temperatures rise from 10.0°C to at least 11.3°C by 2050. By 2100, average temperatures will rise to 12.2°C (climate protection scenario) and 13.8°C (business-as-usual scenario).

- A slight increase in annual precipitation and especially winter precipitation is to be expected in the near and distant future.
- Today Burgenland has recorded an average of 10.1 hot days per year. In the near future there will be almost twice as many, in the distant future even around 25 or 42 days depending on our future way of life and economy.

The aim of the project "Creative Circle"[1] is therefore to develop and implement an so called "energy transition cycle" in Eisenstadt. The energy system of the city will be set up as a circular economy. That means, that the locally available resources and energy flows should be used locally. The local district heating network, the sewage treatment plant and photovoltaic systems form the basis of the project. A large part of the population is currently supplied with heat from the district heating network that is mainly heated with biomass. Currently, a part of the heat goes unused with the wastewater to the sewage treatment plant. This is set to change in the future. The thermal energy in the wastewater will be integrated into the district heating network by using a heat pump, thus closing the "heat cycle" in the city. In this way, the amount of biomass used should be reduced and an upcoming expansion of the district heating network will be supported. Figure 1 provides an overview of this overall concept.

With regards to the electricity supply, a renewable energy community was established that contributes to the local use of locally generated electricity. Energy communities enable the exchange of electrical energy across properties without involving an energy supplier by using the public electricity grid. The electricity demand of the heat pump as well as the electrical demand of the inhabitants of Eisenstadt can be partly covered with renewable energy from the energy community, at favorable tariffs. Another focus area of the project is the increasing overheating in summer and the associated need to adapt to climate change. The energy from the energy transition cycle is also used for the environmentally friendly operation of a multifunctional cooling center, which provides a cool place to shelter from extreme heat free of charge and also functions as a social meeting point. The Cooling Center will be open to all residents of Eisenstadt, be easily accessible and be characterized by multifunctional usability in order to make the space more attractive.

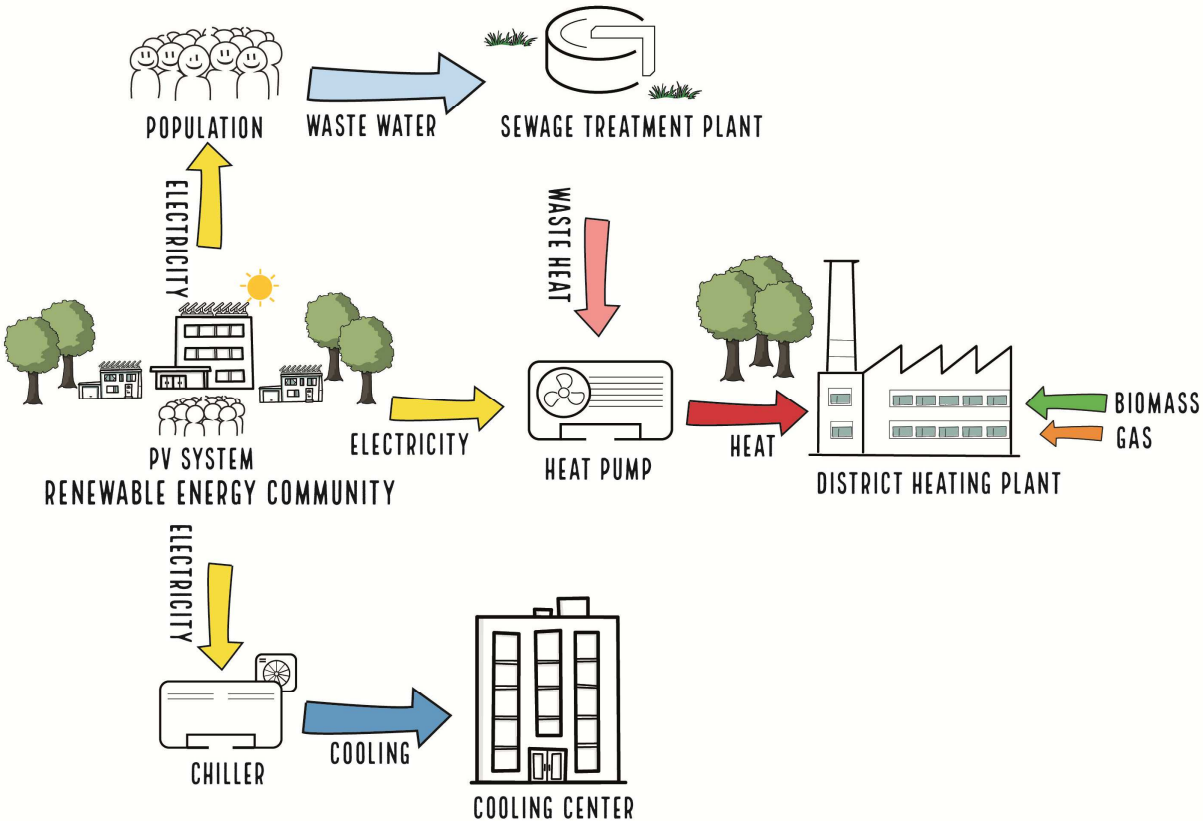

Figure 1: Schematic illustration of the energy transition cycle in Eisenstadt

[1] https://creativecircle.myportfolio.com/

Spending a few hours in a cool environment reduces the risk of vulnerable populations being exposed to heat. Those who adjust their behavior to spend time in a cool place during a heat wave are less likely to suffer from heat wave mortality. A study of the 2003 European heat wave surveyed family members of those who died to determine behavioral factors that influenced mortality. The study concluded that staying in a cooler environment during a heat event was associated with a lower risk of death. [Vandentorren et al., 2008] A meta-analysis of the risks and protective factors associated with heat-related mortality found that going to an air-conditioned room reduced the risk of death by about 66 % compared to those who did not go to air-conditioned rooms. [Bouchama, A., et al, 2007]

Although cooling centers are a widely used climate change adaptation measure in the United States, Europe, and Canada, there are only a few studies that have examined the direct health effects of their use. Most research on cooling centers focuses on an evaluation of implementation and use. While there is a lack of research that directly assesses cooling center use on health outcomes, there is strong evidence that extreme heat is detrimental to health and that staying in a cool environment can help maintain a safe core body temperature and reduce mortality. The research suggests that implementing more comprehensive heat plans that include cooling centers as a strategy has saved lives. Thus, the use of cooling centers should not be a stand-alone measure, but a part of a city's comprehensive heat plan (heat stress response planning). [Widerynski et al.,2017]

There is some evidence in the literature summarized in Widerynski et al. about what supported the implementation and use of cooling centers, such as accompanying communication strategies, public relations, and the involvement of a large group of different stakeholders and multifunctional facilities. The literature shows many different ways in which cities have informed the public about the location of cooling centers and specific heat events. These included issuing heat alerts with relevant information, including providing real-time information, locations on an easily accessible website, and reaching vulnerable populations with brochures and other informational materials. A cooling center that serves several different functions, such as a library or community center, can help attract a wider variety of visitors. [Widerynski et al.,2017]

Barriers or obstacles to accessing or using Cooling Centers include limited access to transportation, fear of leaving home or inability to leave home, not wanting to leave pets behind, populations that do not self-identify as vulnerable, and the general stigma that Cooling Centers are only relevant for "old people." Some individuals were unsure of what to do in a Cooling Center and expressed concern about sitting in a room all day with nothing to do. Many of these barriers can be overcome through awareness and proper planning. Educating the public about what cooling centers are and who is at risk can help increase occupancy and save lives. [Widerynski et al.,2017]

Therefore, awareness-raising measures are another important aspect of the project Creative Circle. The aim is to reach local people, including those groups that have so far been underrepresented in the energy transition and climate policy and to take them along on the path to sustainable energy use and a lifestyle adapted to climate change. In coordination with the municipality, goals and measures for climate change adaptation are also to be anchored in the urban development plan, which is currently being revised.

3 METHOD

The comprehensive research question of the project requires a methodological diversity that includes both, technological and participatory elements. With regard to the technological dimension, the focus is on the integration of renewable energies and the coupling of different energy sectors. This includes the local district heating network, the sewage treatment plant, the local renewable energy community as well as the Cooling Center. In the first step, concepts were drawn up for the individual measures, which will be combined in a further step to form the energy transition cycle.

3.1 Cooling Center

The first step was to carry out a requirements analysis of the Cooling Center and identify possible locations. The requirements were divided into exclusion criteria and so-called location criteria. All locations that fulfill the exclusion criteria were rated according to the location criteria in order to identify the optimal location. The criteria were defined as follows:

- Exclusion criteria:
  - Consumption free area not given.
  - Exclusion of population groups.
  - Barrier-free access not given.

Location Criteria	Description	Weighting
Accessibility	mobility hub, local public transport, within walking distance, intermodal, intervals	30 %
Location	central, presence in the urban space, user frequency, possible added value in the route chain	20 %
Ownership/economy	city-owned real estate, rental or purchase of real estate	20 %
Opening hours	seasonal, ensuring accessibility during predicted periods of heat, including on Saturdays, Sundays and public holidays	10 %
Fulfillment of requirements for awareness raising, knowledge transfer and participation	multifunctional, temporary, permanent - spatially and functionally separated possible or overlapping of functions/uses	5 %
Technical infrastructure	district heatingPV-System, drinking water, etc.	5 %
Structural and legal requirements	accessibility and safety of use, fire protection, statics/strength, thermal insulation, hygiene/health, building regulations, ...	5 %
Feasibility/time horizon	until when can the construction work be completed and the Cooling Center go into operation	5 %

Table 1: Location Criteria incl. weighting of the criteria

Based on this evaluation, two locations were identified, both of which are very suitable for the Cooling Center. One is the foyer of the town hall, and the other is a mobile solution that could be set up in a central but shady location (Domplatz or main square). Cooling concepts were developed for both solutions and presented to the municipality as the decision-maker. The location in the foyer of the town hall was ultimately preferred, although it is still a possibility that additional mobile solutions will be installed in the future if the Cooling Center in the foyer of the town hall is evaluated positively.

3.2 Wastewater heat utilization

A circular energy economy approach is realized by utilizing a heat pump, which will be installed at the wastewater treatment plant site. This heat pump uses the energy from the wastewater to supply heat to the district heating network. To close the energy circle, the heat pump is powered with energy from the local renewable energy community, in addition to the power procured from the grid.

At the moment a biomass heating plant with a total thermal output of 7 MW, supported by a gas boiler, covers the city's heating requirements. A photovoltaic system at the site of the sewage treatment plant and the local renewable energy community contribute to electricity generation. The technical design of the heat pump integration was evaluated according to different sizes of heat pumps (i.e., thermal powers of 0.6 MW, 1.4 MW, and about 2 MW) and variable temperatures (i.e.,) of the heat source (wastewater treatment plant) and heat sink (heat network). Data from the wastewater treatment plant, the heating plant and the district heating network from the last three years as well as forecasts for the future utilization of the heating network have served as the basis for the dimensioning.

Techno-economic analyses show that the biggest heat pump can cover a thermal load of up to 2 MW, which is sufficient to cover the entire summer load of district heating. As a next step, the research includes a detailed analysis of the investment costs for the different heat pump sizes and an evaluation of the associated business models. This will be crucial to determine the optimal size of heat pump to be installed and to calculate the heat production costs. An additional life cycle assessment will provide further evaluation criteria for the comparison between the use of a heat pump and the previous operating strategy.

3.3 Renewable Energy Community

To increase the share of renewable energy sources and to provide incentives to produce and use the energy locally, the EU renewable energy directive has further developed the process of emancipating the end consumers towards active participants in the energy system. Parts of that directive have been transposed to national law in the “Erneuerbaren-Ausbau-Gesetzespaket” in July 2021, which enables the establishment of so-called renewable energy communities in Austria. A renewable energy community is a community of producers, consumers and ‘prosumers’ amongst which renewable energy can be exchanged. In case of renewable electricity, the public distribution grid can be used. To create additional incentives the energy exchanged in the community is subject to reduced grid fees, taxes and levies.

As shown in Figure 1, the energy community can be seen as the central element of the energy transition cycle, as it supplies all three sub-areas (electricity cycle, heating cycle, Cooling Center):

- Local renewable electricity production is brought together by the energy community and distributed back to local consumers.
- The heat pump for wastewater heat utilization will be supplied with energy from the energy community.
- The chiller in the Cooling Center is supplied by the energy community (in addition to the municipality's own PV-consumption).

At the start of the project “Creative Circle”, plans were already in place in Eisenstadt for the establishment of a renewable energy community ("Energiegenossenschaft Eisenstadt"). After consultation with those responsible, the Raiffeisen Nachhaltigkeitsinitiative Burgenland and the municipality of Eisenstadt, it was decided to cooperate and to integrate the aspects of the energy transition cycle described above into this energy community. This cooperation also ensures that this form of organization will continue to exist beyond the duration of the project, thus guaranteeing, that a central element of the energy transition cycle has been structurally integrated and secured for the long term.

3.4 Participation

The involvement of the local population, especially those groups that have so far been underrepresented in the energy transition, is an important aspect in establishing the energy transition cycle. The opportunities for participation and the measures taken and planned in this regard are shown in Table 2.

Electricity cycle	Heat cycle	Cooling Center
Participation as a member of the renewable energy community Participation as a consumer, producer and prosumer Participation through voting rights at the general meeting	Participation as a district heating consumer Automatic participation through the use of waste heat from wastewater	Active participation through the use of the Cooling Center Participation and opportunities for co-design through co-creative (further) development Survey and evaluation of design requirements for the Cooling Center Opportunity for feedback directly in the Cooling Center

Table 2: Participation and opportunities for involvement in the energy transition cycle

4 INTERIM RESULTS

The research project is still ongoing but some interesting interim results have already been achieved with regard to the planning and simulation analysis of the individual aspects of the energy transition cycle.

4.1 Urban development

At the level of urban development and spatial energy planning, the approaches to action are multi-layered and complex. In addition to concrete spatial and technical measures, awareness-raising and integration into strategic planning instruments such as the urban development plan play a crucial role.

The aim of the project is therefore also to reach local people – including those demographic groups that have been underrepresented in energy transition and climate policy so far – and to involve them in the transition towards sustainable energy use.

At the urban development level, the municipality of Eisenstadt is developing an urban development plan in collaboration with external teams of experts. In doing so, the provincial capital is fulfilling an obligation under the Burgenland Spatial Planning Act 2019, which requires all Burgenland municipalities to draw up such a concept by 2026.

The collaboration and integration of the findings and results from the research project therefore represent an unique opportunity to anchor these in a formal, strategic instrument at municipal level and to incorporate topics such as spatial energy planning, climate-friendly mobility and the application of energy transition cycles.

An exchange with representatives of the municipality of Eisenstadt and the utilization of synergies in the further development process have already taken place and are planned to continue. Synergies between the research project and the requirements of the municipality to fulfill the obligations according to the Burgenland Spatial Planning Act 2019 can be utilized.

As one of the previous evaluation of the existing urban development plan of Eisenstadt, it was noted that further planning and concepts are necessary in the area of spatial energy planning as well as in the area of climate-friendly mobility and infrastructural measures. Important goals and approaches for action include (cf. Municipality of Eisenstadt, 2022):

- Further implementation of PV systems on public buildings
- Organising events on the topics of energy-efficient construction/renovation and renewable energy
- Establishment of a community for renewable energy
- Phasing out fossil fuels, especially gas heating, and promotion of alternatives: District heating, geothermal energy, heat pumps, PV systems etc.
- Building renovation strategy to reduce energy requirements
- Expansion and improvement of public transport services / reduction of inner-city private transport
- Expansion of cycling infrastructure
- Sustainable construction
- Unsealing and soil protection
- Greening with climate-adapted trees and shrubs
- Creation of a sustainability and climate protection plan for the city
- Information campaign (events, informational materials, actions) including the creation of a digital information platform
- etc.

4.2 Cooling Center

As first part of the energy transition cycle, this Cooling Center located in the town house of Eisenstadt was completed in summer 2023. The foyer in the town hall was redesigned for the Cooling Center to make the stay as pleasant as possible and to create a social meeting place.

The original concept of the energy transition cycle envisaged cooling the Cooling Center with an absorption chiller using the local district heating network as a source. However, as the town house is not (yet) connected to the district heating network, it was necessary to redesign the operation of the Cooling Center and install a classic compression chiller. But even in this concept, environmentally friendly operation was ensured, and local energy resources were used - the town house, as a municipal building, has its own PV system and is also part of the energy community, i.e. if it is not possible to cover its own needs with its own PV system, the demand is covered by the energy community. The fact that the Cooling Center is operated in the summer months (when most of the solar radiation occurs) means that it is possible to achieve a high degree of solar coverage.

The technical concept was developed by the project, the implementation was commissioned by the municipality of Eisenstadt. In order to keep the cool air on the floor in the open space, an innovative type of air distribution was used. The air is guided across the room by means of textile ducts, which are very finely

perforated, allowing the air to flow out evenly at a slow velocity. These enable pleasant cooling, while simultaneously reducing operating costs. Moreover, the Cooling Center should also become a social meeting place, where the energy transition in Eisenstadt is being driven forward together with the inhabitants.

Figure 2: Left: Opening Ceremony of the Cooling Center, right: Distribution of the cool air via textile ducts (© Sandra Koeune)

4.3 Wastewater heat utilization

The planning of the wastewater heat utilization at the sewage treatment plant was carried out in parallel. It was decided that the heat pump should be able to take over the operation of the district heating network during the summer months. Therefore, a thermal capacity of about 2 MW is needed. Moreover, the heat pump had to be designed for the flow temperature of the heating plant (currently approximately 85 °C). The current layout with such a heat pump, yields a yearly average coefficient of performance of 3.30. Subsequently, the biomass boiler could be deactivated in the summer months (i.e., June to September) and the district heating network could be fully supplied by the heat pump, as shown in figure 3. Additionally, the heat pump is able to substitute the use of the gas boiler, which is a further step towards a fully decarbonized and renewable coupled energy system. A parallel operation of the heat pump and the biomass boiler was not possible in this particular case as the biomass boiler is already operating in the lowest range of partial load operation during the summer months.

The detailed planning and the economic evaluation of the wastewater heat utilization are still ongoing. Initial estimates have shown that the current tariff situation (electricity vs. biomass and heat) makes the economic evaluation of the investment project a challenge. In addition, it is still difficult to estimate how tariffs will develop over the next few years. On the other hand, there are good funding opportunities for the required investment costs and the integration of the heat pump into the energy transition cycle also has a positive effect on economic efficiency.

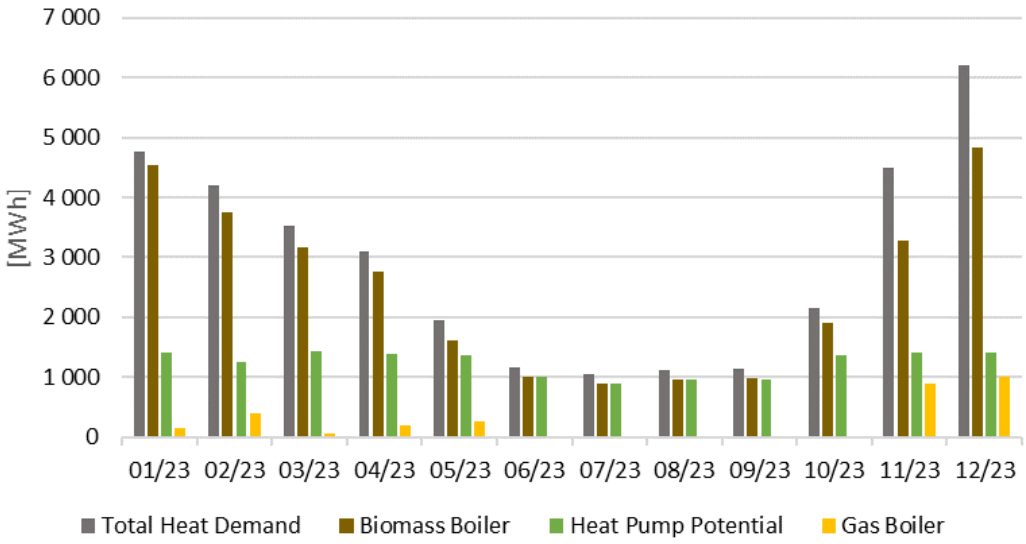

Figure 3: Comparison of the heat demand with heat production and the potential of a heat pump with a thermal capacity of 2 MW based on data from the year 2023.

4.4 Renewable Energy Community

The renewable energy community in Eisenstadt was put into operation in 2022. It is a regional energy community that enables all residents and SMEs in the city area to participate, regardless of whether they have a generation plant (mostly photovoltaic systems) or not. The energy community was started with a small number of participants but is expected to grow strongly over the upcoming months and years. The electricity available within the energy community is distributed fairly among the participants according to a fixed distribution formula. Lower tariffs are charged for electricity purchased via the energy community than for electricity purchased from the public electricity grid. The same applies to producers or prosumers, who can feed their (surplus) electricity into the energy community at favorable conditions. The specific tariffs are adjusted on an ongoing basis, depending on the general development of the electricity market.

Once the heat pump has been installed and put in operation, it is planned that the heat pump will participate in the energy community as an additional consumer so that the power supply can be partly covered by local renewable electricity from the energy community. The proportion of this depends mainly on how the energy community develops in the meantime. As the heat pump is a significant consumer, the additional integration of large generation plants into the energy community would favorable.

5 CONCLUSION AND OUTLOOK

The results of the “Creative Circle2 project so far are very promising. The integration of a heat pump in the sewage treatment plant shows considerable potential for reducing biomass and gas consumption and increasing the efficiency of the district heating network. The local energy community enables increased use of locally generated electricity and helps to reduce dependence on external energy sources.

The Cooling Center in Eisenstadt's town hall, which was already opened in summer 2023, is another milestone in the project. It not only offers a cool retreat on hot days, but also promotes social interaction and exchange between residents. The successful implementation of the Cooling Center shows that the population is actively involved in the energy transition process and is responding positively to the changes.

However, the implementation of the project is not without its challenges. The technical design of the heat pump integration requires careful planning and coordination with the existing systems. Choosing the right size of heat pump, taking the biomass system into account and increasing efficiency are complex tasks that need to be tackled carefully.

In addition, it was shown that social acceptance and participation are of crucial importance. Comprehensive awareness-raising is necessary in order to involve all sections of the population, especially those who have been underrepresented in the energy transition and climate policy to date. The Cooling Center is an important tool here, not only to provide protection from the heat, but also to act as a social meeting place.

The “Creative Circle” project in Eisenstadt therefore shows a promising way how urban energy systems can be sustainably transformed. The integration of renewable energies, the coupling of different energy sectors and the active participation of the population are key components for a successful energy transition. The preliminary results are promising, but there is still work to be done.

The research will continue in order to refine the technical implementation, strengthen social acceptance and ensure the economic viability of the project. The progress made is not only important for Eisenstadt, but can also serve as a model for other urban areas facing similar challenges in the context of the energy transition.

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🏆 *reviewed paper*

Digital Human – Introduction

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1 ABSTRACT

In this article we return again to the idea of representing a person in the modern digital world. In order to make the formalization more correct and meaningful, the classical philosophical heritage was first studied and the conceptual models of a man were formed based on the views of leading philosophers of the past and present. Due to understandable limitations, only a portion of the research in the field of philosophy is presented here. Taking into account modern achievements in computer science, especially in the field of AI, it is proposed to consider a computer model of a person consisting of two phenomena: a human profile and a trace. A computer can work with these concepts, despite the complexity and ambiguity in the minds of many people.

Keywords: digital world, digital human, individual profile, individual track, social group

2 INTRODUCTION

We began this study in 2008 as part of a project commissioned by the US Department of Homeland Security [1]. Because the topic of the project was not directly related to this type of research, it developed rather slowly, sporadically and without serious funding. However, the relevance of this topic is increasing; the successes of such a company as Palantir (USA) [11], confirm the wide interest in such work in the world. It is symbolic that the creation of Palantir coincided with the implementation of our project, thereby confirming the correctness and relevance of such research. In this article we present our self-initiated research in this field, by presenting a new stage in the development of this project in the form of a concept and methodology for building practical systems of such kind in the interests of a wide range of customers. This topic is the ideological basis of our practical work – an intelligent social network that exists in a test version and we hope for its early release for a wide range of users and interested customers. In our previous works, we examined such concepts as “individual” and “collective”, their fundamental ideas, such as “profile”, “trace”, individual and collective “unconscious”. In this article we will try to transform theoretical concepts into forms of elements of computer models, ready for implementation in the form of software tools and scenarios for their use. Once again, we present here the basic concepts of our approach, formalized and with a visual interpretation.

3 PHILOSOPHY OF HUMAN

Before we begin to present a man as an element of the modern digital world, let us turn to the history of philosophy and present the abstract essences of man, formed by famous philosophers. Let us immediately make a reservation that this is our simplified, brief presentation of the ideas of great philosophers in a graphic interpretation. This is a general, conceptual view of man from different philosophers. We also compiled such simplified models for the purpose of further digital interpretation. To fully consider this topic, a different presentation format is needed, at least in the form of a monograph.

3.1 Model of B. Spinoza

The work of B. Spinoza [2] is surprising for a number of reasons. But what is most impressive is his presentation style – it is based on an axiomatic approach. Let us note that formally the first axiomatic approach known to us was formed as a system of geometry described by Euclid in “Elements” approximately 300 years BC. Consciously, the understanding of axioms as a certain set of statements that do not require proof was formed by the middle of the 19th century. Spinoza's idea is shown graphically in Fig. 1-4, (see below). Our interpretation of this model is shown in Fig. 4. Main conclusions from the ideas of B. Spinoza are the following:

(1) Man has a threefold structure: body, soul and spirit.

(2) Spinoza showed some mechanisms of human interaction with nature and the essence of pre-established limitations.

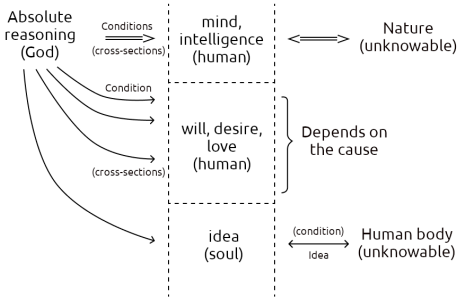


Fig. 1: Model of a human

Limitation of the paper do not allows us make detailed explanations of the figures. But we hope that the rule "a one picture is equal to thousands words" is true. Also it is possible to read original works of Spinoza and other philosophers. Let us present Spinoza's process (process of cognition) in Fig. 2.

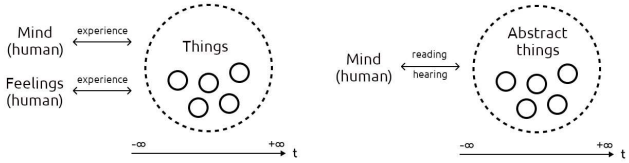


Fig. 2: Cognition of the 1st kind (opinion or objection). The source of falsity

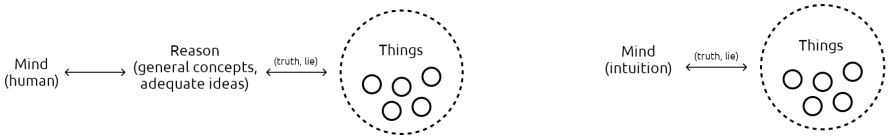
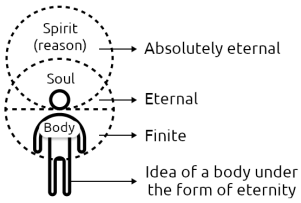


Fig. 3 (left): Cognition of the 2nd kind. Fig. 4 (right): Cognition of the 3rd kind

Using up-to-date terminology: Spinoza's process can be interpreted as a business analytics of a human. And one very important remark: there exists a difference between the soul of a man (M) and a soul of a woman (W). Both halves are present in man and in woman, however, one part dominates the other (M over W or the other way around). M – are digital. W – analog.



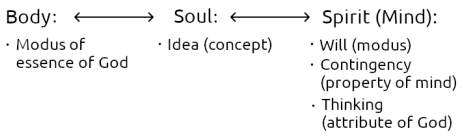


Fig. 5 (left): Interpretation of Spinoza's ideas. Fig. 6 (right): Attributes of entities

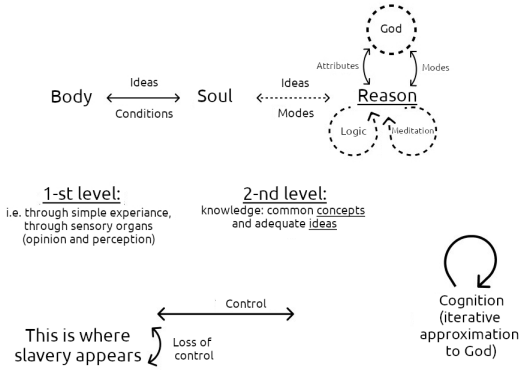


Fig. 7: Processes of cognition for human

3.2 Model of R. Descartes

Descartes clearly highlights the concept of “mind” and also tries to discover the mechanism of human interaction with nature through reason [7]. Thinking is perceived as a category containing the following elements: understand, desire, feel. The soul is perceived by him as a certain set of ideas. Descartes distinguishes between the concept of soul and reason. Reason shapes a person's judgments. The will forms relations towards things. Things are a symbiosis of intellectual (mental) and material entities of the world and consciousness. The symbiosis of soul and body forms such concepts as hunger, thirst, etc. Passions of the soul: anger, joy, sadness, love, ... Feelings: pain, itching, tickling, ...

3.3 Model of I. Kant

Kant considers nature as a “thing in itself” [9]. The main attention is paid to the processes of human consciousness.

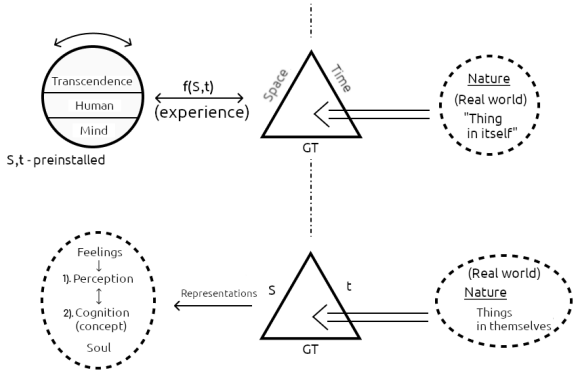


Fig. 8: Interaction of a Human – real World

Let us regard this process below:

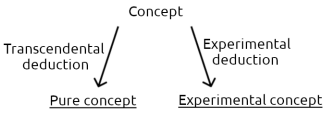


Fig. 9: The process of cognition

Determining the subject of cognition.

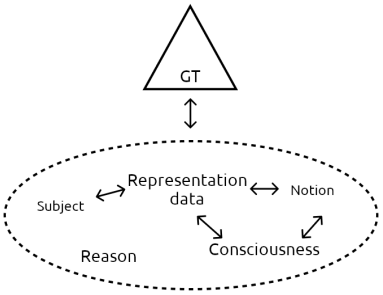


Fig. 10: The process of cognition

To perceive = to correlate representative data with the subject.

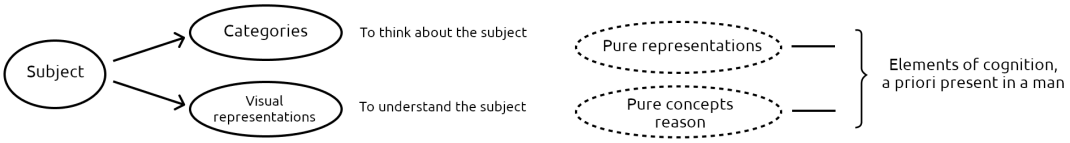
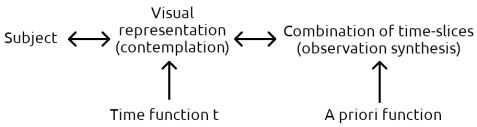


Fig. 11 (left): Relation of representation data to subject. Fig. 12 (right): Concepts capture experience, not the other way around

Processes:



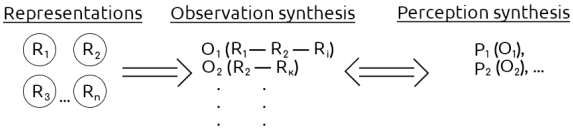


Fig. 13 (left): Synthesis of observation in visual representation. Fig. 14 (right): Synthesis of reproduction of representation

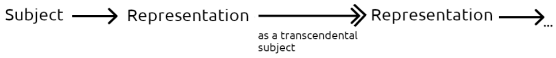
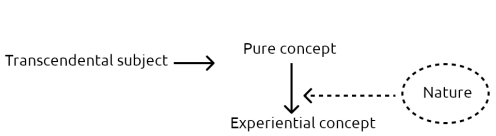


Fig. 15: Synthesis of recognition in the concept



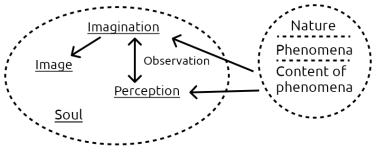
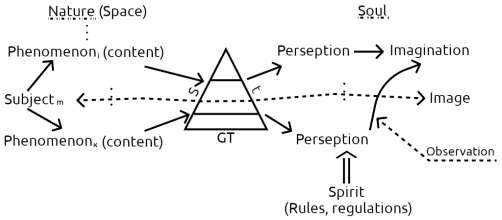


Fig. 16 (left): The connection of the transcendental subject with nature. Fig. 17 (right): Category as cognition a priori



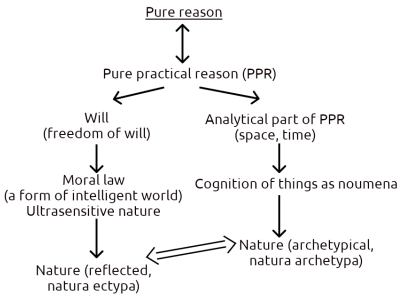


Fig. 18 (left): Human's interpretation of nature. Fig. 19 (right): Kant's idea of "pure reason"

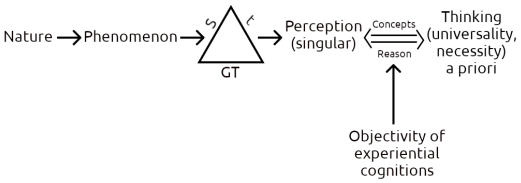
General ability of the soul	Cognitive ability of the soul	A priori principles	Application to:
Cognitive ability	Reason	Conformity to law	Nature
Feeling of satisfaction and dissatisfaction	Judgment	Feasibility	Art
Ability to wish	Mind	Final goal	Freedom

Table 1: Abilities of the soul according to Kant

3.4 Model of G. Hegel

The difference between Mind and Reason [4]:

- Reason deals with finite and conditioned.
- Mind deals with infinite and unconditioned.



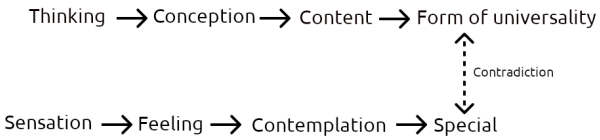


Fig. 20 (left): Concept of mind. Fig. 21 (right): Concept of reason.

Logic breaks down into 3 parts: (1) Doctrine of existence, (2) Doctrine of essence, (3) Doctrine of concept and idea. Nature is an idea in form of otherness. Cognition is carried out through 3 instances: universal, special, singular. Universality – eternal unity of the idea. Singular – the extreme opposite of universality, a form of finite spirit. Special – nature, spirit alienated from oneself. The above concepts of man, his essence and thinking, as a way of knowing objective and subjective reality, are presented for further computer modeling with the aim of creating a computer platform for self-research and for creating digital twins. Let us consider the ideas of a number of philosophers who represent man as a social entity.

3.5 Model of E. Fromm

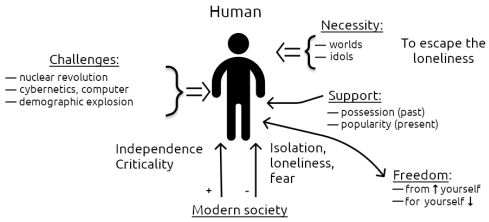


Fig. 22: Model of a human as as a social animal

Escape from freedom [10]:

- obedience to the leader (Hitler, Stalin);
- search for new, secondary ties (renunciation of freedom to gain power from a leader).

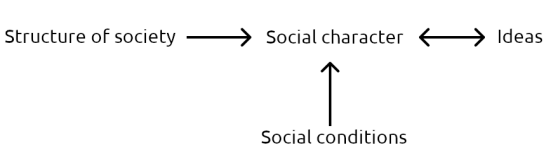
As a result destructiveness!:

- isolation of a person;
- suppression of individual expressiveness;
- transformation of a man into machine;
- formation of insignificance and powerlessness of a person.

The truth: is the most powerful weapon for those who has no power.

Ways to paralyse critical thinking: (1) Information overload. “Experts” assist in this. Results: cynicism and naivety, (2) Destruction of a structured view of the world. Ours is only what connects us due to creative activity.

Specification of the model for a specific human forms social character of a human (ideology + culture). Continuous activity – intense desire for it is the result of loneliness and anxiety. Education – preparing a person for a role in society. Family – psychological agent of society. Pursuit of justice and truth is a part of human nature. Lower middle class is the main driving force.



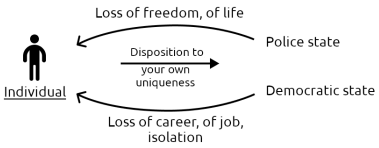
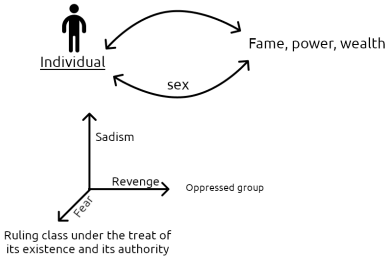


Fig. 23 (left): Social character. Fig. 24 (right): The individual in modern society.



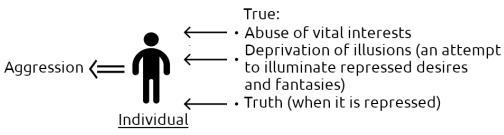
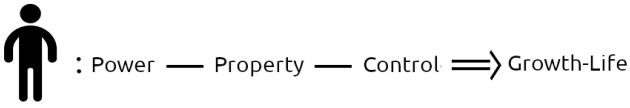


Fig. 25 (left): Individual’s challenges. Fig. 26 (right): Sources of aggression.



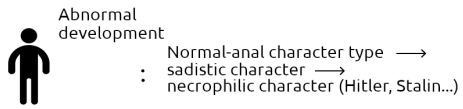


Fig. 27 (left): Desire for destructiveness. Fig. 28 (right): Sources of abnormal behaviour.

This is was in the past. Today: new type of a person exists – a market person. This person is of one thought, of one dimension. Feelings are not replaced, but wither away. Mother of this person is no longer Nature, but a second nature: digital world.

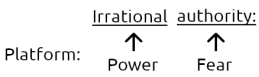
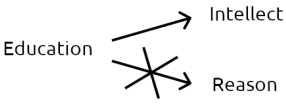


Fig. 29: Irrational authority

Equality = interchangeability != individuality. In-difference = equality != difference.



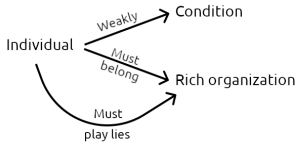
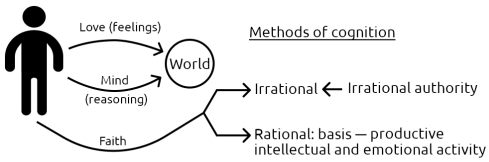


Fig. 30 (left): The purpose of modern education. Fig. 31 (right): Social pressure on personality.



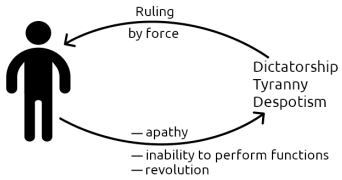
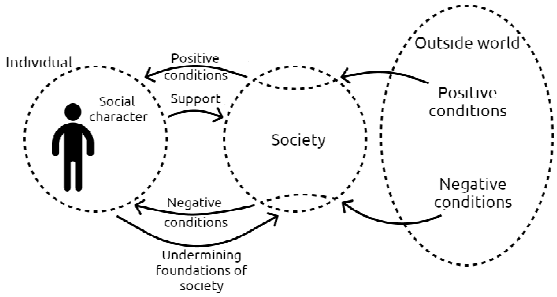


Fig. 32 (left): Methods of cognition. Fig. 33 (right): Negative challenges



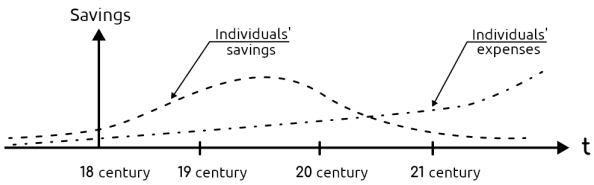


Fig. 34 (left): Formation of an individual's social character. Fig. 35 (right): Transformation of an individual's income and expenses

The prevailing part of inner experience is not realized and for this reason is not controlled by logic, reason, and will. The basis of the unconscious is human irrationality. A person is not free, he is driven by the Id and Super-Ego. K. Marks, B. Spinoza: Human activity is a creative, spontaneous act, possible only in conditions of freedom. Awareness of a reality not realized by human is a condition for social change.

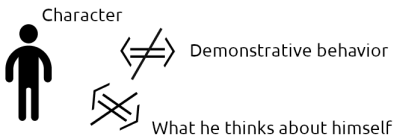


Fig. 36: Estimation of reality.

Social trend: from Patriarchy to Matriarchy.

(1) Elimination of authoritarian systems: dictatorship, wars, conflicts, terrorist attacks..., (2) The defeat of authoritarianism, (3) Women's revolution, (4) Children's and teenage revolution, (5) The myth of consumer's paradise, (6) Matriarchal traditions are increasing: radicalization of youth, group sex, clothing, etc., (7) Reconsidering the central role of the Oedipus complex.

Matriarchy: unconditional love, natural equality, ...

Patriarchy: conditional love, hierarchical structures, abstract thinking, laws, states and justice.

Fromm's model shows the individual's attitude towards society and to such form of society as the State. Here the essence of a person is manifested as his social character. In this light we would like to cite the recommendations of K. Marks [3] for the formation of the social character of modern man:

(1) Explain to modern man that he is suffering, bring this fact to his consciousness. This is especially important to do in rogue countries, where modern slavery is returning at a rapid pace.

(2) Explain the reasons for this suffering: envy, greed, the pursuit of profit, lack of real freedom (slavery), lack of real property.

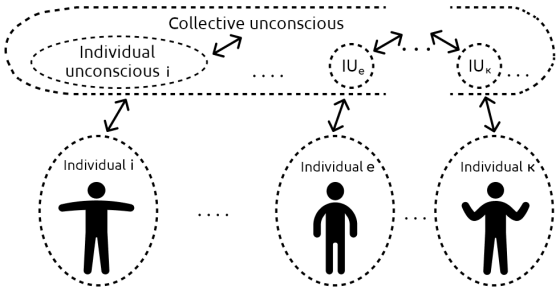
(3) Show a person that he can stop his suffering if he eliminates the causes of this suffering.

(4) Develop a program for liberating people from poverty outlining the principles of a new life.

We limited ourselves here to a brief presentation of Fromm's ideas and did not touch upon the ideas of other philosophers who were engaged in research on the social side of man due to the limited format of this article.

3.6 Model of K.G. Jung

This is the last model that we will present in this paper due to limitations in the amount of material to be published and the format not entirely suitable for presenting such extensive research. But, K.G. Jung's [6] idea of the "collective unconscious" plays a central role in this study, since it actually determines the architectural solution (the main idea) of a digital person specified on the DS. The importance of Jung's ideas also lies in the fact that his hypothesis about the intellectual essence of man is quite close to architectural solutions in computer science when developing large, distributed, heterogeneous systems, including the use of artificial intelligence technologies of various purposes and scales. The importance of Jung's ideas also lies in the fact that it shows the existence of some common part inherent in humanity, which greatly simplifies the development of the projection of each individual onto the DS.



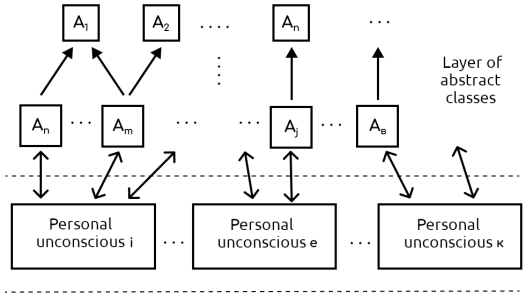


Fig. 37 (left): Interpretation of CU. Fig. 38 (right): CU interpretation by object oriented approach (programming methodology)

Note:

1) The layer of abstract classes is the CU, they only are inherited, but not filled.

2) Personal unconscious – a system of fillable classes that can be available to an individual, but under certain conditions (a) Interpretation in object-oriented approach notation).

b) Conceptual (philosophy) interpretation of a person (intelligent being).

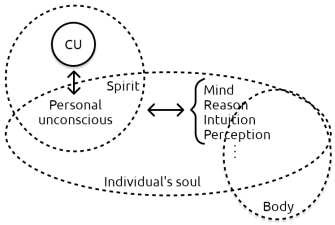


Fig. 39: OOA interpretation and philosophy interpretation of Jung's idea of the collective and personal unconscious.

Classes Ai – are archetypes, universal images that have existed since time immemorial. They manifest themselves through secret teachings, myths and fairy tales.

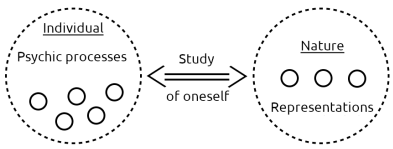


Fig. 40: Individual and the Nature interaction

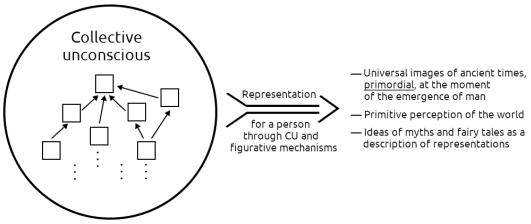


Fig. 41: CU representation for a person

The original experience is lost, as if we have “lost” the developers of the OS and development environments (tools). We are just users!

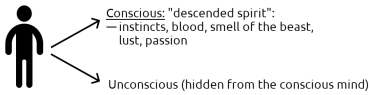


Fig. 42: Two kind of meaning

Anima is a special archetype of many of them. For a man it is a “projection” of a woman. “Not-me”.

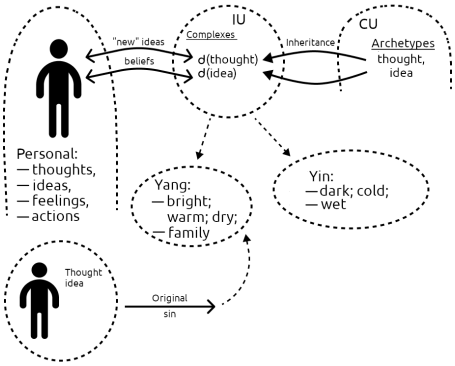


Fig. 43: Anima conception presentation

The projection can be realized only after its appearance.

Love can not be comprehended by consciousness.

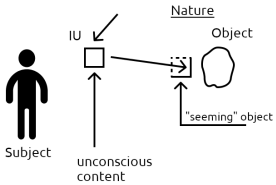
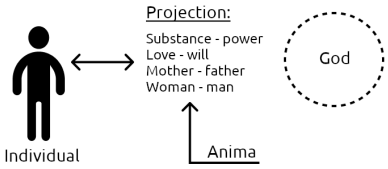


Fig. 44: “Idea” as “Archetipe”

“Idea” – is a synonym of “Archetype”.

There is no difference between humans and other animals.



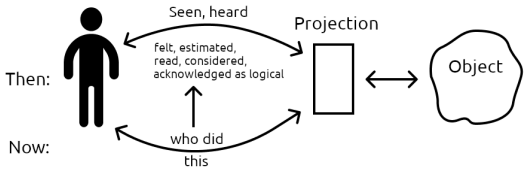


Fig. 45 (left): God and Individual. Fig. 46 (right): Transformation of modern consciousness

In creativity, primary images become visible (Plato).

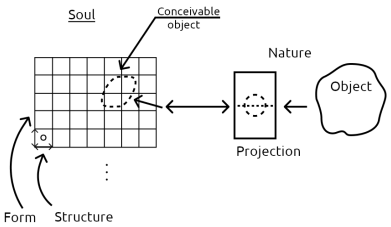


Fig. 47: “Mechanics” of nature and human interaction

Jung believes that everything in this world is based on pairs categories: matter – spirit, etc.

Let us draw brief conclusions based on the reviewed material. The presented material is the basis for the formation of such concepts as “digital profiles” and “digital footprint”. We have given models of various philosophers, but have not formed a universal, generalized model. We believe that such a model will be created only as a result of approbation of a system of models in a global computer network. Such work can begin with the attraction of additional funds from sponsors or other interested parties. We hope that this excursion into the world of philosophical knowledge will make it possible to more clearly present the purpose and importance of such abstractions as “digital profile” and “digital trace”.

4 INDIVIDUAL PROFILE

Before we begin to consider this issue, we should make an important remark that we consider all the abstractions under regard as given in some digital space, i.e. in a generally accepted spatio-temporal context.

Note. By digital space we mean any known algebraic metric space on which transformations are given that have a digital interpretation. Those. all functions are computable on a computer.

Let us make a number of comments. The profile (Pfl) essentially has two representations. Static or physical, dynamic or digital. Static Pfl is closely related to the biological and social essences of man. Dynamic Pfl – with the digital activity of the individual. Therefore, as a result, the individual Pfl has three representations: biological, social and digital (as an interpretation of the previous two). An individual trace has two representations: biological (Physical) and digital. One more important note. We are talking about conscious things that are generally accepted and understandable to everyone. But there is still an element of the unconscious, which in many cases remains outside our consciousness. The unconscious cannot be revealed by the individual (in most cases) directly, only indirectly. One of the goals of our approach is to help the individual identify important elements of his individual unconscious (IU).

IU can be detected in various ways. The direct method is a method based on S. Freud's method. The indirect method is based on the analysis of individual profile (IPfl) and individual trace (IT), as a manifestation of the unconscious in the activity of the individual. This technique may created both through computer modeling (traditional) and using AI methods to identify “inexplicable” actions and decision-making by an individual. To speed up the convergence of Ipfl to the true one, the following option (initial) is proposed. Types of people can be specified (according to Freud and Fromm), and then, by accumulating data and forming IPfl and IT as a representation of the selected type of the unconscious. Based on the principle of maximum coincidence, the type of the unconscious is determined as the most probable.

Let us consider Ipfl as a representation of an individual in his three essences.

4.1 Physical Pfl

These are physical and medical data that form a non-repeating physical “portrait” of an individual. First of all, these are such familiar parameters as height, weight, skin color, hair, dental formula, physique, blood type, blood formula, etc. This should also include mental characteristics of the individual: character type, temperament, etc.

4.2 Social Pfl

This is a characteristic of an individual from a social point of view. A role in a team, social activity, social and ideological position, religion, attitude towards religion, culture and art, as well as many other parameters.

4.3 Digital Pfl

It can be presented as the appearance of an individual, given in digital space (the previous two points). It is characterized by a significant number of parameters and individual topology in the digital space. It also includes parameters such as personal preferences of the digital world, first of all: preferred hardware (desktop PC, laptop, tablet, smartphone, etc.). The type of operating system used, set of applications, social networks and Internet sites visited, etc. Also a very important parameter is the circle of communication in the global digital space with other individuals, organizations, information resources, etc.

Note. We do not have the task of giving a full and complete detail of all the parameters that make up the IPfl. Moreover, the composition of the parameters will be determined by the user himself. Thus, we have just laid out an idea here.

4.4 Individual unconscious

For our study, as we have noted earlier, two approaches are applicable: direct and indirect. In the case of a direct approach, we only have to record the IU in the corresponding class. Then the verification stage is possible, because there is the possibility of various types of errors to be made by a specialist (expert) (psychologist and/or psychiatrist). It is quite possible to develop an intelligent subsystem that can solve this problem. The second option (indirect) is more objective, but requires an appropriate methodology, implemented in the form of an application, as well as objective source data, which is extremely difficult in our time of complete distrust towards computer networks.

5 INDIVIDUAL TRACE

The concept of “trace” may be represented by two abstractions: geographic footprint and digital footprint.

5.1 Geographic footprint

Geographical trace – is the movement of an individual in physical 3D space and in time. In other words, this is a recorded change in one’s own coordinates over a certain period of time , at different scales:

- local. This, as a rule, is: home --- work --- places of rest (entertainment) --- home, etc. It happens within the metropolis (village, city). It has a cyclic period of a working week.
- regional. Sustainable business trips (travel), interests, hobbies, summer cottage, etc.
- global. Typically covers international travel for business, cultural or leisure purposes.

Sources of information that can be used to obtain trace parameters are given by us in our other works.

5.2 Digital footprint

A digital footprint (DF) is essentially the topology of an individual’s activity in a global computer network. DF can also be divided into a number of levels:

- local – this is the level of the enterprise (LAN), or a city.
- regional – city, region, country.
- global – this is the World Wide Web, the entire Internet.

The division is very arbitrary, because the Internet does not have the boundaries that we are familiar with from geography. However, states establish different requirements for internal Internet nodes and often block “undesirable” Internet resources, limiting an individual’s capabilities. Digital space is a kind of coordinate system that can associated with the time scale. By recording nodes (resources) and DS subscribers with a certain discreteness, we get three variants for the trace, which we stated above.

A short conclusion can be drawn. At this stage, we have completed a brief review of the individual for his representation in DS. It is quite obvious, and we have emphasized earlier, that an individual cannot exist in isolation. He needs a social environment in which he can exist properly as a person. But the social environment is not some immense sea of people, individuals.

In the social environment there is also a strong stratification of people according to various characteristics and reasons. A whole system of so-called social (public) groups (SG) is emerging. Let us consider the concept of social group (SG) in more detail.

6 SOCIAL GROUP

By SG we understand two or more individuals connected by at least one common idea, which implies their periodic interaction. Typical examples of SG are: family, any community that is united by a business, a hobby, a common interest or something else. Numerically, SGs are very different from each other. Groups such as a laboratory, unit, department, enterprise and, finally, a political party are formed from the SG. At the same time, the SG is necessarily the interaction of individuals who are members of the SG. Interaction can be direct, or it can be indirect, through another member. SG can be presented by analogy in the same way as an individual, but the fundamental difference is that the SG is a certain system, and not just a certain number of people. Let us consider the main types of SG representations.

6.1 SG profile

Without doubt, SG has the same representation as IPfl. But this is not just a set, or a certain set of Ipfl of individuals included in the SG. But, just like Ipfl, SG-Pfl also has a number of representations similar to Ipfl:

6.1.1 Physical representation

This is a collection of individuals that form the SG. In addition to the totality of individuals, the following characteristics (parameters) are important:

- physical location of the members of the group in physical space (city, streets, apartments, houses, etc.);
- availability and location of technical resources: printing houses, servers, other equipment, such as various types of transport, research equipment, etc.

6.1.2 Social representation

First of all, it is an idea, a party, or something else that unites individuals and is their social distinctive feature. As a rule, social representation is the basis on which SG is based. This might be religious or party idea, program and practical activity. This is what shapes the will of a large number of people, what focuses people's efforts on one idea, one goal.

6.1.3 Digital representation

It represents the digital topology of the SG in digital space, has a systemic property that cannot be reduced to a set of local digital topologies of the SG members. The emergence of a systemic effect leads to the fact that the SG is perceived as some integral physical, social and digital entity, which is identified in this way by other participants (representatives) of the digital world. Each representation can be depicted graphically for more clarity. At the same time, the presentation of topology not only has a visual meaning, but also has a certain significance for understanding many things.

The diagram of social representation of SG is a maximum one in terms of scale. But the principle shown is inherent in any SG and may not always be realized and presented as a certain pattern of activity. It is also obvious that not every SG requires such a level of abstraction. The SG DS as a fragment of the global DS with different scales:

- strategic (global) level management bodies;
- regional level authorities;
- tactical level controls;
- SG members, attracted individuals.

The subdivision of elements of the presentation above do not have geographical significance or scale (global, regional, local), although they may coincide with them. This division (hierarchy) is determined primarily by the level of tasks being solved. It was noted earlier that the entire set of tasks is formed in the "program" - the main document of the party, for example, and is specified in plans and decisions. To solve the formulated tasks, all members of the SG are trained, decisions are prepared and made, planning, management and analysis of the results obtained. We examined the management cycle in our previous works. It should be noted that digital representation is a form of existence of SG in our time, the basis of which is data, information, knowledge and understanding. And in principle, SG can exist without a DS, as it happened

earlier in the recent history of mankind (oral speech, writing, telephone, telegraph, newspapers). However, you will have to get used to it and the operating efficiency and value of the SG will be sharply reduced, and some functions will disappear altogether.

6.2 Trace of SG

The trace of SG is the most complex abstraction, but at the same time it is the most significant and it essentially determines the effectiveness of the SG. That is, the SG is created for a reason, not for the sake of its existence. It is created to achieve certain goals and at the same time solves a number of supporting tasks. Assessment of the effectiveness of achieving the goal can be determined only by analysis of the actions of the SG, which may defined as "trace". Depending on the scale of the SG itself, the footprint can also have different scales: local, regional, and global. But first, let us define what an SG trace is. With an individual trace, everything is more or less clear, since the individual is localized as a physical, social and digital entity. But what SG is – needs to be defined. We showed the profile of SG from various points of view earlier. Taking into account the fact that the SG has emergent properties that no individual (member of the SG) individually possesses, we will also try to formulate the SG-Tr in three entities: physical, social and digital.

6.2.1 Physical essence of SG-Tr

This is a set of individuals. In other words, it. has certain physical properties, such as:

- number of members;
- their physical characteristics (children, schoolchildren, students, workers and mixed groups);
- geographical location (one house, farm, village, district, city, region, region, country, international level), one company, group, cartel, etc.

6.2.2 Social essence of SG-Tr

The social essence of the SG trace is a trace primarily in the minds and consciousness of SG members and other people within an enterprise, metropolis, state or at global scale. It does not necessarily need to be an ideology. Such a social trace could be a conviction in the quality of products, services, lifestyle and much more. A special situation is when the SG is trying to expand its ideological influence, affects the minds and souls of people. Extreme cases of such influence are religion and politics. The question arises: how to identify the social trace of SG? The idea of conducting various kinds of surveys and questionnaires immediately comes to mind. But this is an extremely ineffective method, which may suitable only for political and religious organizations. An analysis of traffic to SG resources (information) on a certain topic may be more objective.

But this is also only an indirect indicator. Ordering a special sociological study is very expensive, time consuming and also a big mistake from the point of view of the objectivity of the results. It seems to us that the most effective way to present the “social trace” is the following:

- assessment of the quantity and dynamics (first signed derivative) of sales of goods (services), presentation of products and ideas.
- assessment of the stratification of society using SG services (children, adolescents, adults, workers in various fields of activity).
- assessment of geographic dynamics at various scales (local, regional and global) of service users.

Note. In this context, we understand services as goods, publications, intellectual activity, ideas, concepts, etc. Services can be refundable, non-refundable and mixed. It all depends on both the type of SG and the type of service.

- assessment of the number of visits to SG Internet resources (web pages, social networks).
- links to SG publications, citations of SG members by other authors and organizations.
- placement of links about SG on the resources of other SGs.

Note. Obviously, in this day and age, social trace is highly correlated with digital footprint.

6.2.3 Digital footprint of SG

This is actually the projection of the SG onto the DS. Despite the limitlessness of the Internet, the projection of a digital footprint should also be considered at various scales. Those are local, regional and global levels. Note that the previously shown digital profile of SG shows a static picture, while Df of SG is dynamic over time. This dynamism is characterized by the following properties:

- first of all, the topology and its transformations into the DS. A change in the number of nodes at various levels indicates an increase in the influence of SGs (increase in number, change in scale) in the society or a decrease in the degree of influence (decrease in number, degradation of scale). A change in the number of connections also indicates the structural strengthening or degradation of SGs.
- primary access types: Wi-Fi, Cell, Wire, Satellite, etc.
- stratification of subscribers: news feeds, social networks, trading platforms, companies, private clients.
- stratification of types of connections: business, education system, training, ideology, interest, etc.

7 CONCLUSION

In this paper, we have briefly, almost abstractly, examined the idea of digital human and the digital reflection of an individual in digital space. To understand such fundamental concepts as space, time, man as a biological and social entity, we turned to the philosophical heritage. Therefore, in the article we presented in a schematic form the views of outstanding philosophers on the questions of what are man, nature, human thinking, its capabilities and limitations.

A large number of people are already present on the Internet, although they are not fully aware of this fact. There are obvious advantages and serious threats. The main idea of our research is aimed at making each person aware of his projection in the digital space in order to studying himself. Also, each individual must understand that any information about himself can have both positive and negative consequences. We also tried to show the deep mechanisms that constitute the essential basis of the individual based on the ideas of leading thinkers over a long historical period. In the future, we intend to develop our research into the creation and trial operation of an intelligent social network in order to study the ideas and hypotheses formed in this article.

In this article, we did not present universal or integrated models of man, nature, thinking processes and perception of objective reality. The task of our next stage of research is the computer interpretation of the ideas presented in this article using modern programming technologies and artificial intelligence.

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Digital Space of a Human: From Philosophy to Computer Science

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1 ABSTRACT

This paper continues the discussion of ideas published in our previous articles for CORP conference related to a concept of a man in a modern world. The greatest attention is paid to the concept of human digital space. This concept, in our opinion, is the key to understanding the role and the place of modern man in the digital era, which has created a number of serious challenges to a man himself and, with certain development, can threaten his basic foundations of existence as a human being.

The paper also draws attention to such a problem as interaction of people with each other and interaction of people with machines.

Keywords: digital space, human digital space, artificial intelligence, modern digital society, computer science

2 INTRODUCTION

This paper makes an attempt to highlight several issues that remained not fully disclosed in previous articles published in the proceedings of the CORP conferences (CORP-2016, CORP-2017) and IF&GIS-2017. First of all, we need to try to define the human digital space as universally (generally) as possible, based on the experience of classical philosophy. There are several ideas, or options, here. The first option is to employ the evolutionary approach. One can go from simple concepts of space to more complex ones. This is how, for example, the idea of space is formulated in linear algebra: point, line, area, volume, abstract spaces of various types. These are relatively familiar concepts and a familiar idea to us. The second option is to apply axiomatic approach, when, on the basis of certain provisions (which are assumed to be true – axioms), some abstract concept is formulated. In previous works, we defined the "digital space" of a person on the basis of the familiar concepts from algebra and geometry, but at the same time such concepts as "space" and "human digital space" were not combined into a single abstract entity.

3 DEFINITION OF SPACE

The concept of "space" is one of the fundamental elements of human thinking and cognition of the world and of oneself. Since ancient times, such concepts as "space" and "time" have attracted the attention of almost all outstanding minds of ancient and modern times. Here are a number of definitions from famous philosophers:

"Space is not an empirical concept which has been derived from outer experiences" I. Kant [1].

"Space is a necessary representation, a priori, that is the ground of all outer intuitions".

"Space is not a discursive or, as we say, general concept of relations of things in general, but a pure intuition."

"Space is essentially one, and multiplicity in it, consequently the general notion of spaces, of this or that space, depends solely upon limitations."

"Space is represented as an infinite given quantity."

"Consequently, the original representation of space is an intuition a priori, and not a conception."

"I doubt that anyone will ever give a correct definition of what space is." [2].

This is the view of subjective idealism, briefly stated.

"The primary or immediate determination of nature is the abstract universality of its being-outside-itself,—its unmediated indifference, space". G. Hegel [3].

"Space is in general pure quantity".

"Space, therefore, is a point, which, however, is non-existent, is complete continuity."

"The unity of these two moments, discreteness and continuity, is an objectively defined concept of space, but this concept is only an abstraction of space, which is often looked at as absolute space".

An example of objective idealism is given.

Everyone can choose an option that is convenient for them. In addition to an objective and subjective view of space and nature in general, there are many other ideas that can be found in special philosophical literature.

4 DIGITAL SPACE OF A HUMAN

The title of this section contains three concepts: "digital space" (there was an attempt to present it in previous works), "person" and "human digital space" (also defined earlier). The subject of this paper is the concept of a "person". We will begin with it, although it is evident that the result will be a thesis and completely incomplete notion, very limited, but necessary for our brief study. A huge number of scientific and popular works are devoted to the study of a man as a complex phenomenon. Since the dawn of human civilization, man has been trying to understand who he is. Information about these works has reached us in the form of legends, myths, works of philosophers, sociologists and, of course, various religious concepts, primarily such well-known ones as Buddhism, Judaism, Christianity and one of the "young" religions – Islam. From a theoretical point of view, it is unfortunately not possible to formulate a clear concept of a "man" at this stage of the development of modern civilization (science, technology, theology). But, for our research, nevertheless, we must do this within the framework of the limitations that exist. This must be done because the object of our study is a man. The subject of our research is the human digital space.

4.1 Object of Research

The established concepts of a "man" today are the following: it is at the same time a biological and social being. But almost all mammals and some other species of the animal world also have this duality to varying degrees. Many religions celebrate the threefold essence of man: body, soul and spirit. This practically corresponds to such philosophical categories as individual, special and general. This, to one degree or another, is noted by such great philosophers as B. Spinoza, I. Kant, G. Hegel, R. Descartes and others.

The concept of "space" exists for almost all living beings. The living space of an animal is expressed in the form of metric measurements, usually in 2D or 3D views. The size of these spaces depends on several factors: the type of animal (mainly its physical size) and its significance: a living space within which the animal feels safe, space for hunting or obtaining food. If another animal crosses one of these spaces, the animal reacts: it either attacks (when its living space is violated) or runs away if it feels threatened. This is a reaction at the level of instincts and acquired experience. Animals such as lions and wolves train in packs in the wild. Narrowing the living space even for animals of the same species (a pack) causes aggression or, at a minimum, discomfort. In similar situations, a person reacts in almost the same way. Everyone knows the so-called "polar disease", when people spend a long time in a closed space and they begin to have conflicts that are difficult to imagine under normal conditions. They begin to be irritated by all sorts of little things in each other that they would not pay attention to under normal conditions. Although, in modern world, in modern society, the concept of "normal conditions" is changing greatly. Take, for example, Southeast Asia and some countries. People in huge cities suffer greatly from the limited living space. This applies to almost all places: housing, work, public transport, promenades and entertainment, etc. These conditions have a strong impact on the person himself, on all aspects of his life. A person ceases to be a natural person, who he was previously throughout his entire existence.

But most of all, modern man is influenced by scientific and technological progress, especially by computer technology. At the beginning of the emergence of computers (the period after the Second World War), computers were created to help people. At the very beginning, they were seen as powerful calculating machines that relieved people of the hard and uninteresting work associated with arithmetic and mathematical calculations. The introduction of the first computers dramatically increased the productivity of scientists and engineers. It seemed that a little more and computers would come closer to the human brain... Although, in computing processes, computers immediately surpassed the capabilities of people. A lot of diverse literature appeared in which the future of humanity was painted in rosy, positive colours. True, there were works, for example by Joseph Weizenbaum [3], warning us that computers also pose a certain threat to

humans. And so, at the very beginning of their appearance, computers were available only to the elect: scientists, engineers, who worked for government agencies, and computers were used in the educational process at universities. Computers have also begun to be successfully applied in production and in the form of on-board computing systems, in aviation and maritime transport. But even then Moore's law began to work. The dimensions of computers and digital devices were rapidly shrinking and, finally, the Internet appeared as a response to the miniaturization and widespread distribution of personal computers. It was personal computers that gave a very serious impetus to the development of computers and digital technology in general. The appearance of personal computers is an almost revolutionary event, which signifies the fact that computers have ceased to be cult things that belonged to a select few, they have become available to almost any person. The widespread use of computers led to a sharp start in the development of various software. Like mushrooms after rain, the massive creation of companies producing various types of software began, from operating systems and development environments to application packages aimed at non-computer specialists. The advent of e-mail and various types of Internet applications has dramatically expanded the communication capabilities of not only software, but of the person himself. Man began to use personal computers in an "unconventional" capacity: as a means of communication, as a means of obtaining information on various subject areas.

The combination of a personal computer with a mobile phone has turned the computer into an integral element, a mean of modern man. This was a turning point. This turning point was marked by the release of such a product as the iPhone. Let us explain this idea in more detail. As was noted earlier, computers were created to help people. All trends in their development and improvement were aimed at meeting human needs. A huge amount of research has been launched into trying to imitate the functioning of the brain, i.e. a computer should be like a person, serving a human. But the situation has paradoxically changed. With the release of the iPhone, the computer industry set a new trend: a person should "move" towards the computer, and not vice versa. Not everyone understood this, and they still do not understand it. Another technology aimed at separating human from reality has appeared just recently. These are social networks. Along with computer games, social networks (SN) greatly deform human's consciousness. "Virtual reality" captivates, and human goes into another world that is more comfortable for him, which he creates for himself, or chooses an existing one, joining various groups in the SN. Instead of living in the real world, human begins to live in a virtual computer world, in which he can very quickly realize himself as he sees fit. The criterion for his self-realization is the number of subscribers and the number of "likes" collected. And here a real business arises, from which many make money without actually doing or producing anything. The virtual world has become a fertile environment for the development of all kinds of anomalies of the human essence; they seem to be in the shadows, clearly not visible, but they begin to influence entire groups of people. The virtual world and the SN have become a convenient platform for various types of criminal structures, in particular terrorist organizations. Terrorist organizations, sects and other negative aspects of modern life feel very comfortable, because there is a massive escape of people from objective reality to virtual reality. There is no need to study, take care of your upbringing, health, defend your role and place in the team, all this can be artificially created in a fictional world. Strange as it may seem, modern computer technologies have a negative impact not only on ordinary users, but also on specialists in the subject area called information technology (IT, Computer Science). And there is a deep reason here.

Its essence lies in the fact that consumer society is increasingly interested in specialists knowing more and understanding less. Almost all modern education emphasizes this idea. The absolute expression of this idea is the test education system and, for example, the unified state exam. The test training system combines two phenomena, two sides of the human personality: training and, at the same time, education. The student must know what the teacher requires of him and answer questions as the teacher requires. Understanding here is not only unnecessary, but also harmful. The student's attempt to understand cannot be met in tests, which are full of errors, inaccuracies and outright incompetence. Such an attempt is usually brutally suppressed by an ordinary teacher, and is perceived by him as an attack on the system into which he has comfortably infiltrated. Understanding requires teaching at a completely different level and requires a completely different level of qualification from the teacher. And, unfortunately, no one is interested in this. A university must have highly qualified teaching staff, who must be paid a decent salary. The question arises: where to find highly qualified teachers and where to get appropriate funding? Students already living in virtual reality do not strive to understand, because in virtual reality (VR) there is also no place or need for understanding,

you just need to know which icons to press and remember the sequence of actions, i.e. some script. And here the most essential property of a person is touched upon, his freedom [5].

"A person is free if he must obey not another person, but the law" [6]. If a person obeys another person, then he is a slave. And lack of understanding automatically means loss of freedom and gaining dependence on another. "Freedom is a conscious necessity" [7]. But without understanding it is impossible to realize necessity in the full sense. Thus, we have every reason to form a new, digital slavery. This tendency was successfully noted and revealed by E. Fromm in his work "Flight from Freedom" [8]. The processes that take place in modern society, namely the voluntary flight from freedom, tend to accelerate, unfortunately. Those negative personality traits and properties, that S. Freud described in his works and were largely confirmed and revealed by E. Fromm, found new ground for their development, but the main part of them is, as it were, in the shadow, in the zone of VR, which for them displaces the objective reality. Such transformations are clearly visible when working with university graduates. The characteristic features of a graduate of a modern university (we are talking about specialities in natural sciences and Computer Science) are:

- lack (complete!) of basic technical education, which was available to students of technical universities of the USSR;
- lack of skills of independent work;
- only knowledge of the basics of their speciality (at best), an almost complete lack of understanding;
- most importantly, people do not understand what it means to understand. They do not have such a culture, they are not used to doing this, because they never did.

This leads to the conclusion: such a person is ineducable, it is impossible to educate him to the level of a developer, he is already only a user, in other words, he is an ideal consumer and nothing more. Apparently, the problem firstly arises in the family and then develops in kindergarten and school. In some universities, this trend is already forming into the corresponding type. Therefore, we can say that a system of social reproduction of consumers has been formed, where there is no system of reproduction of producers. In a broad sense. Especially of producers of intellectual products: new theories, technologies, works of art, etc. Only users and consumers.

What is the root cause of this state of affairs? Let us refer to a number of ideas of E. Fromm from his work "Flight from Freedom". The first idea is that "... modern man is still worried and tempted to give his freedom to various kinds of dictators or to lose it, turning into a small cog in the machine, well-fed, well-dressed, but not into a free person, but into an automaton." Unfortunately, this is a general trend, but what is the underlying reason for this trend? "The structure of modern society affects human in two directions simultaneously. Human became more independent, self-reliant and critical, but at the same time isolated, lonely, and afraid." In such a situation, "free cheese" works very clearly. As a number of studies show, almost 80% of the population are internally ready to exchange freedom for pseudo-comfort. The main thing is to be "like everyone else." But a person internally feels this contradiction; one cannot get rid of it, and VR is the best place to escape from oneself, from real freedom. Flight from freedom, from understanding, in practice takes on monstrous features.

There are a number of examples that many people have come across lately. We are talking about the problem of finding programmers, system architects and project managers. Lately, we have had to train specialists for ourselves, and not always successfully due to the effect of "non-educability." Despite such a sad state of affairs on the market for IT specialists, there is a steady demand for such "specialists". "If he (a Person) is in demand, he becomes someone; if he is not popular, he is simply a nobody" E. From. A person who has mastered a subject area at the level of knowledge, skills and abilities becomes highly demanded, even in such a subject area as IT. This state of affairs is due to another important point – the "washing out" of real owners. Hired managers, "effective managers" of large concerns, pursue their personal interests, because they are not the owners. "With the advent of the monopoly phase of capitalism, the relative weight of both tendencies of human freedom (from and for oneself) changed. Those factors that weaken the human personality benefit, and those that strengthen them relatively lose significance" E. Fromm. The situation is reminiscent of the 15-16th centuries. "The concentration of capital (not wealth) in certain sectors of the economy limits the possibilities for success of private initiative, courage, and intelligence."

Now all the conditions have been created for an accelerated escape from freedom. It is very important for us to understand this in order to determine the conditions for the formation of the human digital space (HDS). The HDS both interacts with real objectivity and shapes virtual reality. Let us consider the main trends that contribute to the escape of modern man into the virtual world, his readiness to part with his freedom.

Independence changes to the possibility of gaining strength, which the person himself is deprived of, this is the search for new "secondary bonds" as a replacement for the lost primary ones.

Note. The primary break is original sin, expulsion from paradise because a person knew good and evil and became equal to God. The birth of a child is also an element of the primary rupture.

The transformation of the individual into an automaton in modern society increases the helplessness and dissatisfaction of the average person. Modern society creates a number of objective preconditions that contribute to the abandonment of real freedom and withdrawal into VR. The main ones (according to E. Fromm) are the following:

(1) Person's own ability to understand really important problems is deliberately hampered. He "drowns" in a mass of chaotic facts and patiently waits for the "experts" to figure out what to do and where to go. These "specialists" also act according to a template or instructions. A person has two feelings: cynicism and naivety.

(2) Destruction of the holistic picture of the world. Radio, cinema, newspapers, magazines, and the Internet have a devastating effect in this regard. In such conditions, few ordinary people, but also only a small number of entrepreneurs can take the initiative.

Such society is very fragile, subjected to strong influence from external and internal factors. The reliance of state leaders on the strength of the parties supporting them only on the basis of the expansion of their ideas is a big mistake and delusion. The depth of penetration of these ideas is fundamentally important. All these conditions and ideas that we defined above must be taken into account when determining the appearance of a modern person. To characterize such person, E. Fromm introduced such a concept as human character. "Not only a person's thoughts and feelings, but also his actions are determined by his character structure" – S. Freud. This corresponds to our concepts of "profile" and "trace" formulated earlier [9]. We believe that such concepts as "profile" and "trace" should be defining when considering the concept of HDS.

Unfortunately, modern society is an aggressive environment for humans. "If he (the individual) insists on his uniqueness, then in a police state he risks losing not only his freedom, but also his life, in some democratic countries he risks his career, sometimes the loss of his job, and most importantly, he risks being isolated". E. Fromm.

The next factors influencing a person's character are fame, power and wealth, which give the owner their sexual superiority with minimal physical data.

"Another serious source of defensive aggression is a person's reaction to an attempt to deprive him of illusions" E. Fromm. This should be taken into account when trying to deprive a human of his VR. We must expect the most severe rebuff. Therefore, a simple, frontal solution will not work here.

And so, we have considered the object of our research – a man. Now let's look at the subject of our research – the human digital space.

4.2 Subject of Research

Apparently, in mathematics it is hardly possible to find an appropriate interpretation of the known types of spaces suitable for describing the HDS. One of our earlier works looked at HDS from a naive point of view. In this article we have already examined what modern man is from a sociological and philosophical point of view. A generalized characteristic of a person can be the concept of a "character". Character is a set of properties of a person that does not include his instincts. (E. Fromm). A character can be understood as a certain meta class, which includes two main classes "profile" and "trace". These concepts were discussed in sufficient detail earlier.

But for this study, it is desirable to include those personality characteristics that S. Freud and E. Fromm spoke about, both static and dynamic. These are already hereditary characteristics, or the results of medical research (tests), as well as acquired characteristics received from relatives, colleagues, and friends. To obtain such data, it is necessary to prepare a list of them. This is interesting, for example, to obtain a social profile

of a specific company by examining the characteristics of all employees. This is important for assessing each employee from the point of view of the company's interests. Let us pay attention to one interesting detail that we did not focus on earlier. The very concept of HDS – what is the semantic load in it? The concept of “digital” here is a service concept; it is not an essence or a reason, but simply a form.

The essence lies primarily in the dual nature of man himself – he is a social and biological animal. For both sides, information is key. On the biological side, information is needed for survival; it is provided by the physical senses: vision, smell, hearing, etc. Each organ forms a certain physical space, within which any living organism receives information about what is happening in the external environment, i.e. outside his physical body. It's a matter of survival in the wild. The nature of obtaining information using various senses is very different; many principles are inherent even in technical systems, such as radar, acoustics, lidars, etc. As for technical systems, here we have a huge number of theoretical approaches that explain the principles of constructing such systems and the principles of their application in practice. There are also a lot of theoretical studies devoted to the study and assessment of the parameters of the environment as the surrounding physical space in which technical means of obtaining information operate.

Currently, we can measure environmental parameters, evaluate the capabilities of detection tools, and plan their use. Physically, the detection space has a very diverse representation and depends on many factors. In this work we will not dwell on these details. Theories, technologies and practice of application are discussed in detail in special professional works. Here it is important to say only that the detection space may be mathematically described (in most cases, but not all) quite accurately, although not entirely simply. The same applies to a person, to his physical level, to imagine the space for receiving information about the external environment with the help of his senses. But, from the very moment of the emergence of humanity, man was not limited solely to the individual capabilities of his senses. He received a lot of useful information for himself from other people and even from animals, being in a certain social environment. This is very important when participating in collective activities and especially when it comes to real time, for example, collective work (construction, agriculture), hunting, fishing, war, etc. At the current moment of research, different types of human spaces can be illustrated graphically, Fig. 1.

Figure 1 a) represents the space of receiving information by one individual from his sensory organs. From this Figure it is already clear that even at the initial level, the level of the individual, difficulties arise. We cannot imagine one, universal space of an individual, because sensory organs are very different from each other. So, vision, if you do not take into account obstacles, can be approximated as a sector (on a plane); in 3D form it is a segment of a sphere. This space is easy to approximate mathematically, although the discovery process itself is not trivial.

The hearing space is the reaction of the hearing sensor to noise (changes in air pressure), also may be simply approximated mathematically. But with the space of smell it is no longer so simple, because the smell spreads mainly by the movement of air masses, i.e. wind. At sea, information also spreads through wind, currents, and tides.

When a trace is discovered, the situation is perhaps the most difficult. The point is this. In the previous cases (vision, hearing, smell) we have a situation where an object deforming a certain type of field is in direct contact, i.e. must exist. Thus it must be physically present somewhere and the distance to it is determined by the environment and the capabilities of the senses. When a trace is discovered, the situation is different. The environment, as it were, “records” information that there was a certain physical object here, but this does not mean that it is here or somewhere nearby, it may no longer exist at all, even physically, but traces of it remain. And here, not only the fact of detection is important, but also the time when the trace was left. Interest in the trail depends on this.

Now, let's return to our previous discussions. An individual uses his senses in two ways. The first option, passive, is needed in most cases to observe and ensure your survival. The second option is active, when the individual wants to do something. But, first of all, in order to do something, the Individual must find and discover this something. This is the eternal problem of the hunter, with which the active phase of human development began. This is also a classic problem in the theory of search and detection of moving objects [10]. The theory of search and detection of moving objects is quite well developed, allowing one to estimate the search potential of the detector, search time and probability of success, i.e. probability of detection. It is also possible to obtain numerical estimates of the capabilities of various types of detection tools. You can

also solve problems of search optimization and distribution of search efforts. For the case when an individual discovered a trace, the search task could also be solved, but it is necessary to know the time of existence of the trace or the time of leaving a trace. These are not trivial tasks. The meaning of its solution generally depends on the initial data.

Let us briefly summarize the consideration of case a) Figure 1. Constructing a human information space even at such a simple level (physical abilities of an individual) is a very difficult task. It is impossible to imagine such a space in general terms, therefore, we have to consider different types of spaces and different analytics. It should be especially emphasized that we considered only the case of one individual.

Consider the case shown in Figure 1 b). This is the case when the interaction of two or more individuals located within the detection space of each (vision, hearing, ...) is considered. In this case, the ability to use one's physical abilities (vision, hearing, ...) increases sharply due to teamwork. This can be seen in examples from the wild, where it is clear that most animals are herd animals. This dramatically increases the survival rate of the species, regardless of whether it is prey or predator.

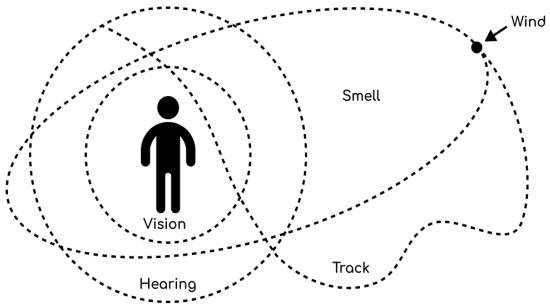

Fig. 1a: Types of human spaces. a) information space of one human

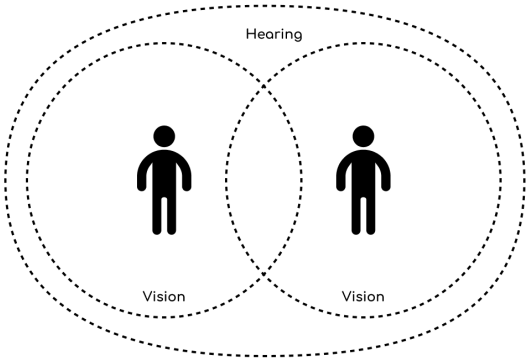

Fig. 1b: Types of human spaces. b) information space of human group (current time)

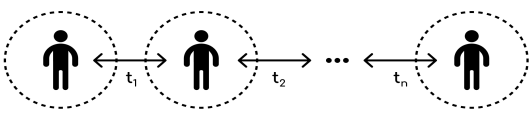

Fig. 1c: Types of human spaces. c) information space of social environment (current&relative time)

Figure 1 c) shows a case unique to humans, when a certain social environment is formed: family, clan, city, state. Here the information fields become almost unlimited, but not all information is available, the available information is not always immediately available upon request, i.e. on-line. Here we are dealing with delay, when not only the information itself is valuable, but also the time of its receipt or delay. Unlike the animal world, the human social environment provides the individual with unlimited opportunities to obtain the necessary information. An important feature of the social environment is that it provides accumulation, storage and access to various types of information. At the very dawn of humanity, information was passed on from mouth to mouth and simply remembered. Then a written language appeared. The Talmud is one of the first books, according to some scholars. This book ensured such stability and vitality of the Jewish people. The fundamental difference between the digital human era and past eras is the following:

- most information may be accessible to anyone in real time, or close to real time;
- access not only to information, but also to any devices connected to the network is available;
- continuous monitoring of the environment and other important objects, including humans, is ensured;
- you can get a lot of services on-line (pay taxes, make an appointment with a doctor, get an initial consultation with a doctor, send tests and take much more);
- social networks, Internet services, artificial intelligence methods and tools (for example, ChatGPT) form parallel (virtual) reality. And the most important. An individual has the ability to control and customize this VR, which is now almost the most important incentive to escape from objective reality.

If we remember again that a person has two sides: biological and spiritual (social), then we can say that the biological side (its physical capabilities) can be formalized, because it is close to the technical means of detection that the natural sciences have learned to design, evaluate and apply. As for considering the social aspect of a person as an opportunity to receive diverse information, there are no established approaches, much less theories and practices. The complexity of this research lies in the fact that when we begin to use technical devices, such as the Internet, sensors, how to evaluate this information from the point of view of the individual's capabilities? Yes, there is an information field (space), but it cannot be connected to any of the physical spaces that we examined earlier, determined by the physical capabilities of the individual. The digital world, digital space, as it were, expands the capabilities of the individual to infinity, to the planetary level.

But how to formalize this? Let us turn once again to the concept of "space". From a philosophical point of view, space and time are independent categories. Some philosophers understand them as objectively existing (G. Hegel, for example), while others assume that these concepts are given to the human mind (I. Kant), that is, as if pre-established by God for the study of the external world as a phenomenon of some essence, a thing-in-itself that cannot be known. In mathematics, space can be formalized and defined as a certain set on which a measure can be specified (metric spaces). For simplicity of reasoning, we present the simplest types of space. For example, a linear space on which the Jordan measure is given. For ordinary consciousness, this could be a line, as an example. The elements of this space are points on the line, that is, the coordinates. And everything that is line can be given, defined by coordinates and vectors. If we consider a plane, then here we have two coordinates and every object on the plane can be defined by these coordinates. Using coordinates, more complex objects can be specified than in linear space. All objects can be specified by a set of coordinates, properties and a transformation system.

In this association, what is the digital space as a source of information?

It can be shown that the HDS can be attributed to a certain type of topological space. And the "split" of the "digital individual" does not have any decisive significance. Let us try to go from simple to complex, to imagine the space of a computer and a computer network. A computer's CPU is entirely determined by its memory, both permanent and RAM. RAM is stored for a relatively short time, until the computer is turned off. Long-term memory is stored much longer, until the end of the storage device's physical lifespan. Information in memory is stored in memory cells (zero or one) that are specially organized to allow recording and reading. For correct writing and reading, an addressing system is set over the memory, which can be simple, or can be quite complex. In general, an addressing system can be represented as a collection

of linear spaces. The specific organization of the memory system depends on the design features of the hardware, the operating system and the purpose of the computer. We will not dwell here on such important and fundamental aspects of working with memory as “dynamic memory”, pointer arithmetic, etc. Despite the complexity of organizing computer memory, it can be represented as a system of linear spaces, simple enough. This is what applies to a personal computer and smartphone. But it is almost impossible to imagine autonomous operation of a computer today. All of them (computers) have turned into certain elements of the global network. The most primitive capabilities that were obvious just recently are now impossible to implement locally. Cloud technologies contribute to this, because businesses are interested in reducing the cost of computer work. The global network, unlike a local computer, offers a number of new services, such as:

- on-demand services, almost everything is translated into this technology, even software development tools. The advent of online artificial intelligence is further shifting storage and analytics from local to the cloud. The local computer is increasingly becoming an interface and access point, rather than a place for storing and processing information. Let us pay special attention to this!cloud technologies and services. The previous point is primarly based on them.
- processing of big data, but this requires huge resources, which, as a rule, are not available on a local computer and their cost for private use is extremely expensive.
- robots and intelligent assistants.

This view of modern automation of society forms a number of analogies with theoretical proposals and examples formulated in the works of K. Jung.

4.3 Definition of a Human

We have examined the object and the subject of our research. At the same time, the object of research was presented by two sides, biological and social, while its essence was not formalized or defined. It turned out that we considered the individual as a device, as some element of a global, local or individual network. In principle, from a certain point of view it is correct and quite effective for solving a number of problems and understanding certain social processes. But a person is not a simple mechanical device and not a simple biological object. The problem of a human is an eternal problem that humanity has been working on for more than one millennium. The idea of human as a dual entity, biological and spiritual, is in some cases very superficial and not clear. This is a simple statement of phenomena, without an analysis of entities. In many religions and ancient teachings, human represents a substance consisting of several orthogonal entities, such as body, soul and spirit, which are integrated into a single whole for a certain time. This idea can be schematically represented in Fig. 2 as some coordinate system. But it should be noted that each coordinate depends on time, and the time function for each coordinate is different, very different from the others. For example, if the X coordinate (defines a physical body) has a clear definition area (beginning and end), then others, apparently, are not so simply defined and can have an infinite length, i.e. from to . They can take the form of some periodic functions with variable amplitude and phase. Most likely, the functions will not be periodic. There may be other “nuances”. So, if the “soul” exceeds the maximum value, then, quite possibly, the development cycle of human ends and he no longer returns to the physical body.

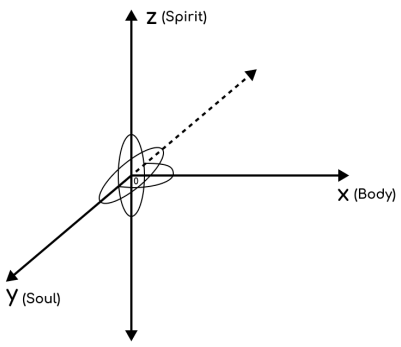

Fig. 2: Abstract diagram of the concept of man.

If the “soul” falls below the minimum level, then development stops and a complete “reboot” occurs. What this “reboot” is not yet clear. Maybe the essence changes, becomes no longer “human”.

The diagram in Fig. 2 represents one development cycle, limited by the life (existence) of the body. With this idea, it is clear that the substance of a human cannot be limited to one cycle (the existence of one physical body). Let us consider the relationship between three entities: body, soul and spirit, Fig. 3. Let us give a brief computer interpretation.

The spirit is pure transcendence, something beyond. Software developer, or source text, formulated and formalized plan, a human will (Arthur Schopenhauer).

The soul is the connection between the biological and the transcendental. Integration of “this” and “that” side. It is like software for hardware.

The body is a physical realization, a “hardware” for representation in the material world and the possibility of material interaction.

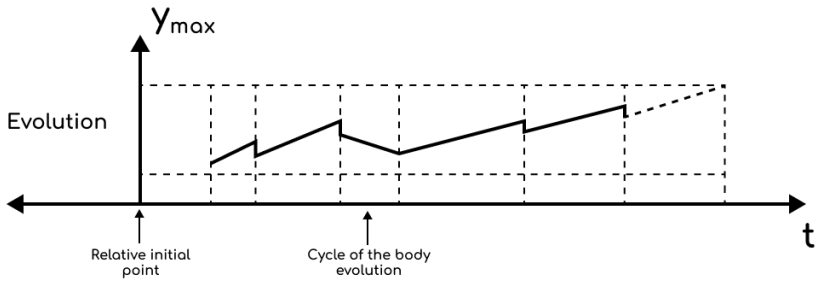

Fig. 3: The first approximation of the entities: “body”, “soul” and “spirit”. b) Soul

Let us consider the interaction of three entities: “body”, “soul” and “spirit”, Fig. 4. Note that this is a very primitive analogy for the general idea. An analogy with the development of software and hardware systems in practice. The developer of “software” for hardware installs it on a specific “hardware”, taking into account the specifications of the hardware on which the software is installed and taking into account the support of all elements and components of the hardware, such as the central processor, motherboard, peripheral devices, information input-output ports, and much more. The installed primary software (operating system, for example) is like a “representation of the Creator,” i.e. has many degrees of freedom and options for modernization and self-improvement, as well as for degradation.

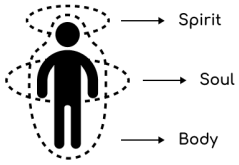

Fig. 4: Human interaction

Returning to Fig. 3, we should note that, considering human as an entity of three parts, these parts have the following properties:

The body is a property of singularity, i.e. it is unique and singular and cannot be repeated. The price to pay for this is limited existence.

The soul is special, i.e. inherent in a certain class, for example, the class of physical bodies. It may have no restrictions on existence.

The spirit is a common, basic idea (G. Hegel), does not depend on, but unites classes of souls and bodies. This is a certain invariant of a person that cannot change under any circumstances, it is eternal. This idea is expressed in a simple formula of a Russian officer of imperial Russia: life to the Tsar, glory to the Fatherland, honour to no one.

If we take into account the evolution of this approach, which was shown in Fig. 4, then in this case such concepts as “space” and “time” lose their original meaning. They exist only at the level of existence of the “history of the singular,” i.e. a specific physical body, and are given “pre-established” (I. Kant) to this body, so that it (a person, an animal) can exist on the scale of existence of one cycle of its body. In this case, there is no past and future, there is a series of experiments, evolution, or a spiral along which you can move in different directions; there is also no concept of “up” and “down”. Assuming that all cycles are “recorded” and “stored” in the “clouds”, there is no difficulty in “playing” any of them again, making certain changes. In our view, or in the view of one cycle, it means “turn back time”, i.e. back and also to the future. Thus, we can assume that our World is a huge, cyclical experiment, where there are no such familiar concepts as space, time, past, future, for humans there is only the present.

Note. The concept of “soul” can also be decomposed into the following three entities: reason, mind and the imaginary part, that which is “on the other side” and is connected with the “spirit”. By analogy with a computer, the mind is a connection, a mechanism for integration with the physical body. The mind is a functional, business analytics essence of a person.

This interpretation raises a number of questions.

(1) What kind of global experiment is this?

(2) How does the “spiritual” world relate to the “physical”, what is the fundamental difference?

If we turn to the Bible and the idea of original sin, we get the following in a simplified form. Adam and Eve lived in paradise, and then they tasted the fruit from the “tree of knowledge”, learned that there is good and evil, and thereby decided to approach the level of the creator, God. But what does this idea mean in terms of Computer Science knowledge and in terms of our previous interpretation? We will try to consistently answer the questions that have arisen. Initially, according to the Bible, it turns out that man was immortal, or simply lived in another World, quite possibly not material in our understanding. Then why did he suddenly move to the combined world and become physically mortal (from the point of view of the physical body)? It is quite possible that at some stage someone decided to “fit in” to the experiment without the knowledge of the “Administrator”, or this is an element of the experiment. Man has now become a full-fledged participant in the experiment on the physical level, a living participant with capabilities (some) close to the capabilities of the Creator himself. It is quite possible that before this there were many preliminary experiments with the concept of “living”, as a synthesis of the material and spiritual. And then, at a certain stage, a man and the entire living world were introduced into living nature as the main participant in the experiment. Modern robotics is also moving towards this.

We return again to our fundamental question: what kind of experiment? It is quite possible that people (humanity and the entire animal world) are a huge, distributed computer and/or a system of primary sensors. In the active phase, during the day, or during wakefulness, a man is a direct participant; at night, in the sleep phase, he works as an element of the “matrix”, his resources are simply loaded with activity that is not under the control of his consciousness. It is likely that we are not yet able to even approximately answer the question of what the essence of the experiment is. To do this, you again need to turn to primary sources, to the primary knowledge that was in the regions of Mesopotamia, India and the Himalayas, as well as to the primary versions of the Bible and the Koran.

We briefly examined the essence of man and his interpretation from the point of view of the natural science approach, from the point of view of Computer Science. The next issues that are interesting to consider are the division of a person into a man and a woman (will be discussed in our other work) and the interaction technology.

5 TECHNOLOGY OF INTERACTION

We have examined the probable levels of interaction between the constituent parts of a person: spirit, soul, physical body. At the same time, another question arises: how, on the basis of what "protocols" (Computer Science), do people interact with each other at various levels: spiritual (spirit, soul) and physical? A graphical interpretation of this idea is shown in Fig. 5. This also applies to interaction with other entities of the living world, as well as with the inanimate world. For simplicity of reasoning, let us turn to what a man himself created. For, according to I. Kant, man could not create anything other than what he represents himself and what the Creator "pre-established" for him. Let us turn to Computer Science, where any interaction is based on a certain "protocol" – this is a formalized system of basic concepts for the interaction on various levels of information processing: the signal level (interaction with the fields of the external world, living and inanimate entities), these are primary devices and sensors, the level applications, the database level and the level of visual interfaces for human interaction. The level of interaction between various elements of both hardware and software has apparently reached its maximum value. From the digital transformation of analogue fields of the external environment to a system of ontologies that represents the intangible world of abstractions and concepts of which the human intellect is only capable. We return again to the original question in the following form, based on a specific example: on the basis of what can a person learn to speak a human language? It is impossible to learn this from scratch. The proof of this is simple – not a single animal has learned to fully speak human language. Thus, a person has a number of physical features that allow him to speak. These features are already pre-established and belong to all people, regardless of race or nationality. Here we do not mean the physical characteristics of the human body that make it possible to form sounds and hear them.

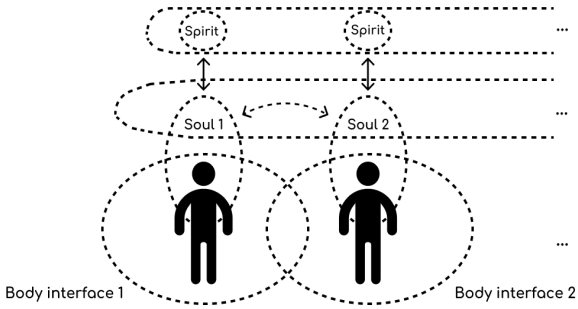

Fig. 5: Interaction between people

Carl Gustav Jung introduced such a concept as the "collective unconscious", as a certain set of archetypes – some pre-existing, primary forms, abstractions [11]. It is logical to assume that people can interact with the physical and spiritual worlds through different, "pre-installed" archetypes. This is the basis that people, and even animals, can interact with each other, while many of the mechanisms of interaction are apparently not realized by them. Those people who can use and "see" archetypes become magicians, sorcerers, or, in extreme cases, hypnotists.

6 CONCLUSION

The authors' views on the concept of man from the point of view of Computer Science in modern digital society presented in this work are far from complete, often naive and worked out thematically. We just wanted to draw attention to problems that seem obvious to us.

It should also be noted that we tried to give a definition of interaction space, which may not be clearly presented and understood by us. But it is necessary to take it into account, especially in the context of the concept of the HDS. It is absolutely clear that in terms of the possibilities and strength of interaction and influence on a person, no HDS can even come close to comparing with the mechanisms of social influence, which are still quite strong. But at the same time, one should not ignore the fact that the HDS can become a

space for the preparation, stimulation and launch of unconscious archetypes, both for a specific, immediate individual, and for an entire people (state), or a specific class of society.

The questions formulated in this article seem relevant to us and their relevance will only increase in connection with the trends that have now clearly emerged: the deepening of automation and its implementation in all spheres of human existence, the intensive introduction of artificial intelligence tools and methods and increasing people's trust in artificial intelligence, i.e. to the machines.

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🏆 *reviewed paper*

Does City Smartness Improve Urban Environment and Reduce Income Disparity? Evidence from an Empirical Analysis of Major Cities Worldwide

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1 ABSTRACT

Urban policymakers often advertise their cities as smart, emphasizing the wide–scale adoption of internet technologies, innovation activities, and the number of universities the city hosts as proof of successful transition towards greater smartness. Question, however, remains whether the accumulation of these attributes results in tangible benefits for local residents. To answer this question, we compare different metrices of city smartness with several indicators of intra–urban income disparity and environmental performance, using data available for 100+ major cities worldwide. As the analysis indicates, the proliferation of internet technologies and the number of universities the city hosts, i.e., popular ways of advancing "smartness", are not related to either intra–urban income disparity or environmental performance of cities per se. We thus suggest that the transition of cities towards greater smartness should be focused on people's needs and ICT-using skills, not on ICT proliferation per se. To the best of our knowledge, this study is the first that links the level of city smartness with intra–urban income inequality and environmental performance of cities and substantiates these links empirically. By accumulating this knowledge, the study helps to understand better the smart city phenomenon and its impact on urban development.

Keywords: smart cities, social inequalities, environmental quality, planning, worldwide

2 INTRODUCTION

The emergence of the smart city (SC) concept in the early 1970's resulted from a wide–spread dissatisfaction with traditional urban planning models that dominated decision–making at the time (Hall, 1988; Stübinger & Schneider, 2020). According to these models, cities are designed as high–density buildings and transportation hubs (Garde, 2020; Stübinger & Schneider, 2020), rather than places that serve residents' needs (Girardi & Temporelli, 2017). The introduction of the SC concept was aimed to change this paradigm by integrating information and communication technologies (ICTs) into the city management in order to improve urban services and the quality of life (QoL) of local residents (Hall, 1988; Marsal–Llacuna et al., 2015; Komninos, 2018; Mokarrari & Torabi, 2021; Sharif & Pokharel, 2022).

A common expectation is that, as cities become smarter, they can expectedly offer more effective solutions to various urban issues, such as poverty (Klevchik, 2019), societal inequality (Sampson, 2017; Martin et al., 2018; Richmond & Triplett, 2018), and environmental degradation (Katz & Bradley, 2013; Shelton et al., 2015; Cui & Cao, 2022). To achieve these objectives, cities deploy diverse ICT solutions that accumulate inputs from various sensors to monitor ongoing changes in the urban environment. The most prominent examples of smart ICT systems include the "The LuxTurrim5G Ecosystem" in Espoo, Finland that provides ultra–fast Internet connectivity, and the "SensorWebBike" system that helps to assemble air quality information in Syracuse, Italy (Lebrusán & Toutouh, 2020). In addition, various ICT tools are deployed to address vital urban challenges, such as online traffic management, and security issues. For instance, municipal authorities can use smart information systems to receive and accumulate information and respond quickly to disasters and emergencies, such as extreme weather events, fires, floods, landslides, etc. (Gath-Morad et al., 2017).

Establishing places of higher learning and encouraging innovations are two other popular strategies of advancing city smartness (Rinaldi et al., 2018; Masik et al., 2021). As Ardito et al. (2019) point out, cities ranked high on the urban smartness scale, often host numerous universities and colleges, and provide tens of thousands of well–paid high–tech jobs (Manville et al., 2014).

Prominent SC examples are London in the UK, Tel Aviv–Yafo in Israel, Barcelona in Spain, Dubai in the UAE, and Singapore. These cities employ a range of ICT tools and solutions that offer individually–tailored

information and services to their residents (Stratigea, 2012; Novotný et al., 2014; Lee et al., 2016), increase resource use efficiency (Mingay & Pamlin, 2008; Aletà et al., 2017; Wendling et al., 2018), monitor air pollution remotely (Estrada et al., 2019; Ranjith Reddy, 2019), and help to optimize road traffic (Bubel & Szymczyk, 2016; Mitchell et al., 2018; Ameer et al., 2019). Examples of such smart innovations are gondolas and electric stairs in Medellin, Colombia that not only improve urban commuting but have also been a source of pride for the local community (Eberlein, 2014).

The TransMilenio and Bus Rapid Transit (BRT) systems in Bogotá, Columbia and Rio de Janeiro in Brazil, are two other examples of smart urban innovations that provide fair access to intra-urban mobility for people of different socio-economic strata (Peraertz, 2016). The multi-disciplinary information center in Rio de Janeiro is another prominent example of smart-city functioning that receives, processes and coordinates information from various sources, such as surveillance cameras, traffic lights, and medical response teams, helping to respond to ongoing events and save lives (Gath-Morad et al., 2017).

Previous studies of the SC phenomenon investigated the effect of smart technologies on QoL in urban areas (Navarro et al., 2017; Stanković et al., 2017); inclusivity problem (Giffinger & Lu, 2015; Meijer & Thaens, 2018; Lee et al., 2022); energy use (Nagy et al., 2019); job creation (Barba-Sánchez et al., 2019), and preservation of the natural environment and its resources (Cavada et al., 2016; Evans et al., 2019; Asteria et al., 2021). However, one important question seems to have escaped the research attention almost entirely:

Do smart cities actually make life better for their residents, by improving environmental conditions and reducing intra–urban income disparity?

The present study is aimed to answer this question, by examining 100+ major cities worldwide, using the most recent data, available for the year 2020 collected from different sources, including databases maintained by the World Bank, OECD, the World Meteorological Organization (WMO) and others. The cointegrated dataset that was formed during the study consists of 23 indicators, reflecting socio–economic, environmental, and technological aspects of the urban development, such as population size, per capita gross domestic product, environmental performance metrics, various innovation indices, e–government development index and others. To the best of our knowledge, the study is the first that looks into the association between city smartness, on the one hand, and intra–urban income inequality and environmental conditions in cities, on the other, and investigates these links empirically.

The results of the present analysis demonstrate that a city's progress towards greater smartness does not necessarily translate into more intra-urban income equality or tangible environmental benefits for the local residents. The main reason is that not all the tools and strategies, adopted by cities to advance "smartness," help to achieve these objectives. In particular, we found no evidence that popular ways of advancing "city smartness", such as proliferation of internet technologies and increasing the number of universities the city hosts, are associated with either smaller intra–urban income disparity or better environmental conditions in cities per se. As we conclude, in order to be successful, transition of cities towards greater smartness should focus on people's needs and enhancement of human skills, such as e.g., improving proficiency of ICTs use, and not on a simple accumulation of ICTs features in cities per se. As we suggest, the knowledge, gained in this study, can help decision-makers to develop informed policies focusing on people's needs and skills of using ICTs, instead of promoting the spread of ICTs in cities as a goal in itself.

This chapter is an abridged version of the paper published by these authors in Sustainable Cities & Society (2023(96): 104711). The remainder of this chapter is organized as follows: In Section 3 our methodological approach is presented, and the data collection method is described. In Sections 4 and 5, the study's key findings are reported and discussed. Conclusions and recommendations are formulated in Section 6, and this section also outlines the study's limitations and discusses directions for future research.

3 MATERIALS AND METHOD

3.1 Cities under study

The present analysis was carried out using data on 100+ cities worldwide (see Figure 1) thta are frequently mentioned by previous studies as localities with smart attributes (Caragliu et al., 2011; Anthopoulos, 2017; Komninos, 2018; Ameer et al., 2019; Sánchez–Corcuera et al., 2019; Luo et al., 2020; Ozkaya & Erdin, 2020; Hajduk, 2021).

The cities in question range in size from 100K to 31M residents and are located on six continents – Asia (22), Africa (1), North America (27) and South America (14), Europe (33), and Australia (4), – thus representing all the regions of the world.

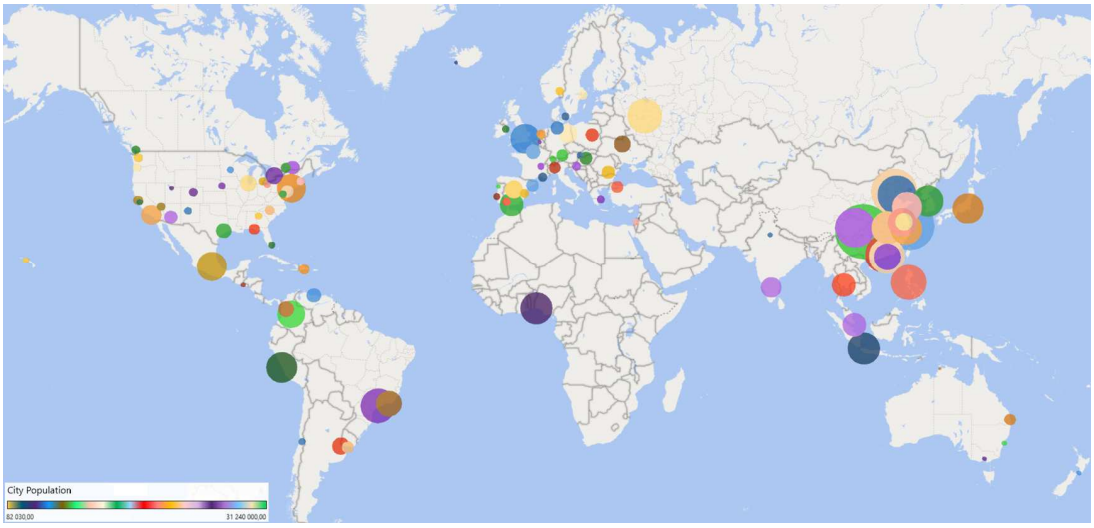

Fig. 1: Geographic location of the cities under analysis graded according to their population size, residents

3.2 Performance measures

The following three performance indicators – plume air quality index (AQI), urban green cover (UGC), and GINI inequality index, – are used in the analysis as dependent variables. Each of these performance metrics is important in its own right, as discussed in brief below.

AQI is an important measure of environmental performance, due to its ability to estimate the overall air quality in cities, by weighing concentrations of different air pollutants and accounting for combined effects (Li et al., 2017; Karavas et al., 2021; Suman, 2021). Importantly, the index converts concentrations of different air pollutants into a single value that simplifies analysis (Joshi & Mahadev, 2011; Suman, 2021). For the present study, the values of the index in question were obtained from the Plume Labs database (Plume Labs, 2021), in which it is estimated by combining information on the following five commonly monitored air pollutants: ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2), particulate matter of under 10 µm diameter (PM10) and particulate matter of under 2.5 µm in diameter (PM2.5) (Plume, 2019).

UGC provides city dwellers with a variety of products and ecosystem services that contribute to climate-change mitigation and adaptation, improve human health and well-being, contribute to biodiversity conservation, while reducing the disaster risk (Salbitano et al., 2016). UGC is a widely used measure of urban environmental performance due to its ability to estimate the level of greenery per an areal unit (or per capita) using remote sensing imagery and spatial analysis tools (Van de Voorde, 2017). For the present study, the values of the UGC index for individual cities were obtained from the Landsat database (U.S. Geological Survey, 2021b) and processed using the MultiSpec system (Purdue Research Foundation, 2021) and the EarthExplorer tool (U.S. Geological Survey, 2021a).

GINI is one of multiple measures of intra–urban income inequality. Other commonly used inequality indices include the Dahl Index, the Hirschman–Herfindahl Index, the Theil Index, the Atkinson Index, the Kolm Index, and others (Coulter, 2019). In this study, we opted for the GINI index, due to its ease of interpretation (Sitthiyot & Holasut, 2020) and the availability of the index calculates for different geographic units, including major cities (Osberg, 2017). The values of the index in question vary from 0 to 1, with 0 standing for perfect equality and 1 indicating utter inequality (Morton & Blair, 2015; Hejduková & Kureková, 2017; Sitthiyot & Holasut, 2020). In previous studies, GINI was found to be closely associated with societal fairness (Klevchik, 2019), and QoL in general (Marsal–Llacuna et al., 2015).

3.2.1 Measures of city smartness

The selection of specific SC performance indicators for the present analysis was based on a systematic analysis of previous studies, in which various SC metrics were used (Lombardi et al., 2012; Albino et al., 2015; Silva et al., 2018; Marchetti et al., 2019; Lim et al., 2019; Li et al., 2019). In our previous study

(Dashkevych & Portnov, 2022), these indicators were classified and systematized, helping us to identify 48 most commonly used SC empirical metrics, grouped into three main categories – economy and technology, environment, and society, – with the indices being ranked according to the frequency of their use in empirical literature (see Table 1).

To simplify the data collection and analysis, we selected nine most frequently used metrics, marked in Table 1 by asterisks. As sustainable development explicitly assumes a balance between social, economic, and environmental objectives (de Jong et al., 2015), the selected metrics chosen evenly represent the three main dimensions of sustainability – economy/technology, environment, and society, – by including three categorization criteria into each group. In previous studies, these measures have been used, alone or in combination, to estimate the level of city smartness and to measure urban performance in general (Lombardi et al., 2012; Aelenei et al., 2016; Mohanty et al., 2016; Liu et al., 2020; Ozkaya & Erdin, 2020; Hajduk, 2021).

Empirical metrics		Data source	Keywords
Economy and Technology	Access to public free Wi–Fi (the number of wireless access points)*; Number of startups*; Innovation cities index*; Broadband subscriptions per 100 inhabitants; Percentage of households with access to Internet; Web Index; Share of people who order goods or services over the internet; Number of users of sharing economy transportation per 100 000; Percentage of public parking spaces equipped with real–time availability systems; Percentage of public transport lines equipped with a real–time information system; Labor productivity; GDP per capita; Change in gross household income; Hourly wage; Purchasing power parity; Number of jobs created; Unemployment rate	Scopus, Web of Science Core Collections, ScienceDirect	city; urban area*; settlement*; urban region*; metropoli*; township*; smart; sustainable; criteria*; measure*; index*; metric*; parameter*
Society	Number of universities in the city (or number of students per 1,000)*; Happiness index*; E–Government development index*; Proportion of population with secondary and higher education; Expenditure on education per capita; Expenditure on leisure and recreation per capita; Corruption perceptions index; Share of residents participating in online platforms; Number of online government services; Extent to which public amenities are available within 500m; Decrease rate in travel time; Access to basic health care services /waiting time; Percentage of the city area covered by digital surveillance cameras; Emergency service response time; Number of transportation fatalities per 100,000; Number of violence, annoyances and crimes per 100,000; Access to public outdoor recreation space – public outdoor recreation spaces (m2) within a 500m radius from homes; Increase in ground floor space for commercial or public use; Life expectancy; Morbidity and mortality; Social inequality (GINI index or similar)	Scopus, Web of Science Core Collections, ScienceDirect	city; urban area*; settlement*; urban region*; metropoli*; township*; smart; sustainable; green; criteria*; measure*; index*; metric*; parameter*
Environment	The number of real–time remote air quality monitoring stations*; Environmental health and ecosystem vitality (Environmental Performance Index)*; The number of electric vehicles charging stations per registered electric vehicle *; Share of the city water distribution network monitored by smart water systems; Percentage of rain and grey water re–used to replace potable water; Percentage of the city population that has a door–to–door garbage collection with an individual telemetering of household waste quantities; Proportional share of the wastewater pipeline network monitored by a real–time data tracking sensor system; Percentage of street lighting remotely managed by light management systems; Percentage of buildings (or housing units) with smart energy or water meters; Proportional share of public buildings equipped for indoor air quality monitors	Scopus, Web of Science Core Collections, ScienceDirect	city; urban area*; settlement*; urban region*; metropoli*; township*; smart; sustainable; green; criteria*; measure*; index*; metric*; parameter*

Table 1: Empirical metrics commonly used by empirical studies for measuring the level of city smartness

3.2.2 Control variables

Population size is one of the most important indicators of urban development (Yamagata & Seya, 2013; Luo et al., 2020), because largest cities are often most productive due to intense competition (Kötter & Friesecke, 2009; Hummel, 2020) and knowledge spillover (Glaeser et al., 1992; Abel et al., 2012), but often lag in environmental performance, due to high volumes of traffic and elevated concentration of production facilities (Lin & Egerer, 2020). GDP per capita is another important measure of urban development since higher incomes are associated with QoL, as well as with better environment performance (Carli et al., 2018; Li et al., 2019; Azizalrahman & Hasyimi, 2020). We thus included these two measures as potential predictors for AQI, UGC, and GINI values in the study cities. Additional variables, used in the analysis as controls, were capital city status, city area, population density, democracy index, average temperatures, elevation above the sea level, precipitation, and latitude. As previous studies show, these variables, alone or in combination, help to explain urban performance (Roy & Yuan, 2009; Heider et al., 2018; Romano et al., 2020; Gough, 2021; MacManus et al., 2021), which justify their inclusion as predictors into the present analysis.

3.3 Data sources

The availability of data for a cross-city comparison is an important consideration due to the fact that the dataset for the analysis needs to be not only inclusive but also comprehensive. To ensure that the

performance indicators used in the present study are fully reliable and comparable, the data from the present analysis were assembled from international databases, including the World Bank (The World Bank, 2021) and Organization for Economic Co–operation and Development (The Organisation for Economic Co–operation and Development, 2021) databases. The data for the analysis were collected for the year 2020, which were the most recent data available in these databases, at the time of the analysis's initiation. Concurrently, environmental and physical data, such as average temperatures, elevation above the sea level, precipitation, air pollution, and latitude, used in the present analysis as control variables, were obtained from the World Meteorological Organization (World Meteorological Organization, 2021), Climate–data.org (Climate–data.org, 2021), GeoDataSource (GeoDataSource, 2021), Aqicn.org (The World Air Quality Index project, 2021), and the Yale University environmental health and ecosystem vitality (environmental performance index) database (Yale University, 2021). The complete list of indicators, covered by the analysis, and their data sources are specified in Table 2.

Indicator		Description
Econ. and Techn.	Access to public free Wi–Fi	Number of wireless access points, from 0 (lowest) to 1 (highest)
	Startups	Global cities ranking of startups (0 to 235)
	Innovation cities index	Innovation index (0 to 100)
Society	Higher education	Number of universities or other higher education institutions with BA, MA and PhD programs (from 0 (lowest) to 1 (highest))
	Happiness index	Evaluation scale running from 0 (very unhappy) to 10 (very happy)
	E–Government development index	From 0 to 1, with 1 corresponding to the highest–rated online services provision and 0 to the lowest
Environment	Real–time remote air quality monitoring stations	Number of real–time remote air quality monitoring stations in the city, from 0 (lowest) to 1 (highest)
	Environmental health and ecosystem vitality	Environmental performance index, from 0 (worst) to 100 (best)
	Electric vehicles charging stations (EVCSs)	Number of EVCSs, from 0 (lowest) to 1 (highest)
Response variables:		
Environmental conditions		Overall air quality index, which brings together the concentration values of different air pollutants, measured from 0 to 300 (extreme pollution peaks – over 200)
		Urban green cover per capita, m2/person
Income inequality		GINI inequality index is from 0 to 1, with 0 representing perfect equality and 1 representing perfect inequality
Control variables:		
GDP		GDP per capita, $US (ln)
Population		Population size residents, residents (ln)
Geographical location		Latitude, dd

Table 2: Empirical criteria used in the study for the SC classification and analysis

3.4 Research hypothesis

As established by empirical studies, SCs help to advance economic development and improve transportation (Ismagilova et al., 2019), provide better health care and reduce resource consumption (Muktiali, 2018). Yet empirical evidence, accumulated to date, is rather contradictory regarding whether SCs lead in environmental performance and show less intra–urban income disparities, compared to cities with fewer attributes of smartness (Graham, 2002; Hollands, 2008; Becchio et al., 2016; Mundoli et al., 2017; Chamoso et al., 2018). Therefore, the following operational hypothesis was posited for empirical verification in this study:

H0: Cities that incorporate multiple "smart attributes" do not exhibit, ceteris paribus, less income inequality, or better environmental conditions, compared to cities with fewer attributes of smartness. Alternatively:

H1: City smartness is significantly associated with less income inequality and better environmental conditions in urban areas.

If H1 is correct, different metrics of city smartness should emerge as statistically significant predictors of the dependent variables under analysis – i.e., GINI, AQI, and UGC, – upon controlling for potential confounders (see Subsection 3.2.2). Otherwise, we shall reject this hypothesis.

3.5 Statistical analysis

To validate H1, we analyzed the integrated dataset in three consecutive steps (see Figure 2). First, we estimated bivariate correlations between SC different metrics, to determine the degree of collinearity between them. As several SC metrics (e.g., "innovation index", "e–government development index", "number of startups" and the "number of air quality monitoring stations"), were found strongly collinear

(r>0.6, p<0.05), the principal component analysis (Jolliffe & Cadima, 2016) was used, to extract "orthogonal," i.e., uncorrelated, components for subsequent analysis. The principal component analysis (PCA) and multiple regressions are frequently employed analytical tools, suitable for the analysis of large, multi-variable datasets with multiple, often collinear predictors (Portnov et al., 2018; Burton, 2021), such as that used in the present study. To facilitate comparison, all the metrics were converted into categorical variables in the IBM SPSS v.27 software, using its "Transform" module (IBM, 2021).

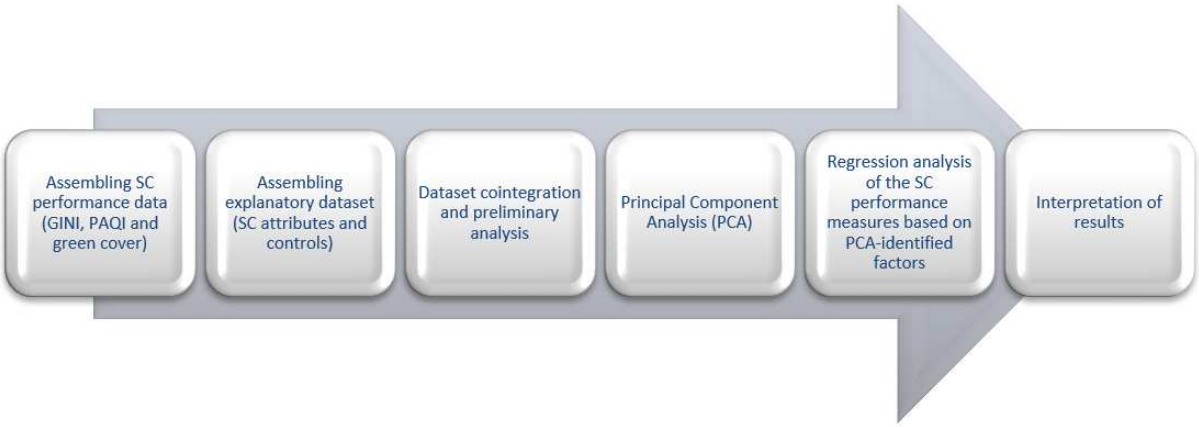

Fig. 2: Study flowchart

The PCA analysis is a multivariate statistical technique that helps to identify the smallest number of hypothetical constructs, also known as factors, that can parsimoniously explain the covariation observed among a set of original variables (Watkins, 2018). By defining orthogonal (i.e., uncorrelated) factors, this transformation helps to facilitate the use of standard regression techniques, in which strongly collinear variables can lead to an estimation bias (Jolliffe & Cadima, 2016). In particular, the analysis was run next, using the following generic regression equation:

$$Pik = b_0 + \beta_0 \cdot SCF_{il} + \lambda_0 \cdot CONTR_i + \varepsilon_i, \quad (1)$$

where Pik is vector of k–performance measures of city i (k=1, 2, 3; GINI inequality index, k=1; k=2: AQI; k=3: UGC); SCFil is vector of SC attributes of city i, represented by l–orthogonal factors extracted; $CONTR_i$ is vector of control variables, including GDPpc ($US, ln), latitude (dd), population size (residents, ln), capital status (yes/no), etc.; b0, β, λ are regression coefficients and ε is a random error term.

In the initial stages of the analysis, additional variables, such as city area, population density, elevation above sea level, average temperatures in summer/winter, democracy index, monthly average rainfall days, and monthly average precipitation, were also considered. However, none of them emerged as statistically significant and were eventually dropped from the analysis.

The 5% probability level (p<0.05) was set as the acceptable level of statistical significance (Gowda et al., 2019). During the analysis, the normality of regression residuals, as well as multicollinearity and heteroscedasticity were monitored (Ainiyah et al., 2016; Abdullah, 2018), and the principal component analysis was applied, as previously mentioned, to substitute the original components by the factors extracted, when the multicollinearity assumption was violated (p<0.05). In addition, the normality of regression residuals was examined using P–P plots and the results were found to be satisfactory. The analysis was performed in the IBM SPSS v.27, software using its descriptive statistics, factor analysis, and multiple regression analysis modules (IBM, 2021).

4 RESULTS

4.1 General trends

As several metrics appear to be strongly collinear, -- viz.: "innovation index" and "e–government development index" (r=0.811; p<0.01); "happiness index" and "environmental health and ecosystem vitality" (r=0.764; p<0.01); "e–government development index" and "environmental health and ecosystem vitality" (r=0.732; p<0.01); "happiness index" and "e–government development index" (r=0.710; p<0.01); "the number of startups" and "the number of air quality monitoring stations" (r=0.569; p<0.01); "innovation

index" and "happiness index" (r=0.548; p<0.01); "number of wireless access points" and "number of universities" (r=0.480; p<0.01). Considering these correlations, we extracted uncorrelated components (i.e., factors), as detailed in the next subsection, to be used in subsequent regression analysis.

4.2 Factor analysis

The results of the factor analysis, performed using the PCA method (Jolliffe & Cadima, 2016), are reported in Table 5. As evidenced by Table 5, three separate factors were extracted as underlying dimensions of the nine original SC metrics (see Table 2). The first factor (F1) is strongly and positively correlated with the "innovation index", "happiness index", "e–government development index", and "environmental health and ecosystem vitality" (r=0.770÷0.919; P<0.01) but does not correlate significantly with any technology adoption measures analyzed (p>0.2).

Variable	Rotated Component Matrix		
	F1	F2	F3
Number of wireless access points	–0.157	0.052	0.864
Number of startups	0.076	0.887	–0.024
Innovation index	0.766	0.214	–0.217
Number of universities	–0.145	0.135	0.797
Happiness index	0.851	0.017	–0.186
E–government development index	0.917	0.075	–0.067
Number of air quality monitoring stations	0.067	0.854	0.189
Environmental health and ecosystem vitality	0.867	0.030	–0.061
Number of electric vehicles charging stations	0.512	0.487	0.357
Rotation Sums of Squared Loadings			
Total	3.222	1.826	1.636
% of Variance	35.804	20.292	18.177
Cumulative %	35.804	56.095	74.272

Table 3: Factor analysis of the SC metrics. Notes: Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization.

This factor can thus be termed "innovativeness, smart government, and ecosystem vitality." The second factor (F2) correlates strongly with the "number of startups" and the "number of air quality monitoring stations" (r=0.850÷0.879) and can be thus termed "startups and air quality monitoring". The third factor (F3) has strong positive correlations with the "number of wireless access points", and the "number of universities" (r=0.791÷0.860) and can thus be termed "higher education and internet access." These three factors jointly explain ~74% of the original variables' variation, with F1 capturing 36% of that variation, F2 – 20%, and F3 – 18% (see Table 3).

4.3 Regression analysis

The results of the regression analysis of the factors influencing intra–urban income disparity (GINI) and environmental conditions in cities (AQI and UGC) are reported in Table 4 for statistically significant variables only, as identified by the stepwise regression analysis procedure.

Variable		Model 1A			Model 2A			Model 3A		
		ba	tb	VIFc	ba	tb	VIFc	ba	tb	VIFc
(Constant)		0.73	3.95**	–	44.05	14.55**	–	15165.14	2.90**	–
SC factor	Factor 1 (Innovativeness, smart government, and society)	–0.10	–5.57**	1.22	–18.90	–6.21**	1.00	0.20	1.96*	1.13
	Factor 2 (Startups and ecology)	–	–	–	–	–	–	–	–	–
	Factor 3 (Internet access and education)	–	–	–	–	–	–	–	–	–
Population size residents (Ln)		–0.32	–2.50*	1.22	–	–	–	–883.96	–2.47*	1.00
GDPpc, $ (Ln)		–	–	–	–	–	–	–	–	–
Latitude		–	–	–	–	–	–	–53.47	–2.64*	1.00
No of obs.		101			101			101		
R2		0.24			0.28			0.11		
R2 – adjusted		0.23			0.27			0.09		
Fd – stat		15.53**			38.60**			6.20**		

Table 4: Factors affecting the income inequality and air qualities in the cities under analysis (Method – stepwise regression; only statistically significant variables (P<0.05) are included). Notes: see comments to Table 6. Model 1A: GINI inequality index as dependent variable; Model 2A: Plume Air Quality Index as dependent variable; Model 3A: Green cover per capita as dependent variable.

As evidenced in Table 4, Factor 1, "Innovativeness, smart government, and ecosystem vitality", is negatively and significantly associated with the dependent variables under analysis (Model 1A: b = – 0.102; t = – 5.600;

P<0.01 and Model 2A: b = – 18.781; t = – 6.157; P<0.01), while in Model 3A, estimated for UGC, it is positively associated with the dependent variable under analysis (Model 3A: b = 0.205; t = 1.955; P<0.05). In particular, as Table 4 shows, this factor tends to reduce, all other factors kept constant, income inequality and air pollution in the study cities (measured by GINI and AQI, respectively) and increase UGC. Notably, neither Factor 2, "Startups and air quality monitoring" nor Factor 3, "Higher education and internet access", emerge as statistically significant predictors of either GINI, AQI, or UGC (p>0.05). Concurrently, population size is statistically significant in Model 1A (GINI: b = – 0.33; t= – 2.517; p<0.05; Table 7), while GDPpc (UGC: b = 1408.220; t= 2.366; p<0.05; Table 7) and latitude (UGC: b = –74.448; t= –2.954; p<0.01; Table 7) are statistically significant in Model 3A.

5 DISCUSSION

The main objective of the study was to investigate the relationship between the level of city smartness, on the one hand, and intra–urban income inequality and environmental conditions in cities, on the other, which have been largely overlooked by previous studies. Our conclusion is that a city's progress towards greater smartness does not necessarily translate into more intra-urban income equality or tangible environmental benefits for local residents. An apparent reason is that not all the tools and strategies, adopted by cities to advance "smartness", help to achieve the above objectives. In particular, we found no evidence that popular ways of advancing "city smartness", such as proliferation of internet technologies and increasing the number of universities the city hosts, are associated with either smaller intra–urban income disparity or better environmental conditions in cities per se. This result thus leads us to reject H1. As we conclude, in order to be successful, transition of cities towards greater smartness should be focused on people's needs and enhancement of human skills, such as e.g., improving proficiency of ICTs use, and not on a simple accumulation of ICTs features in cities per se.

The absence of significant links between intra–urban income inequality and environmental performance of cities, on the one hand, and the scope of Internet proliferation and air pollution monitoring, on the other, is rather an unexpected outcome. The matter is that decision–makers, in an attempt to make their cities smarter, often place an emphasis on the proliferation of internet technologies, by providing e.g., city–wide broadband Internet access and installing multiple sensors for urban management and monitoring (Mitton et al., 2012; Zanella et al., 2014; Bibri & Krogstie, 2020; Syed et al., 2021). According to Kenny (2003), who examined the impact of Internet on economic growth and QoL in the OECD countries, Internet access has a long–term positive impact on economic development and QoL. As also noted by García–Mora & Mora–Rivera, (2021), Internet access is an effective mechanism that contributes to decreasing poverty and inequality. Yet the present evidence–based study supports none of these expectations. In particular, our study detects no significant association between either GINI, AQI, or UGC and the number of air quality monitoring stations or the number of wireless access points, that is, performance metrics, incorporated into Factors 2 and 3 extracted by the factor analysis. An apparent reason is that cities might actually become more unequal through the use of ICTs, because the poor always have less access to such technologies and are less skilled in their use (Graham, 2002). In other words, the availability of new technologies does not necessarily lead to their adoption, and the pace of ICT adoption by different population groups is not always uniform or fair. By the same token, "packing" cities with ICT tools do not necessarily have a positive impact on the environment either. As noted in several previous studies (cf., inter alia, Slob & Lieshout, 2002), additional space created, or resources saved with the help of ICTs, are eventually absorbed by new activities that lead to more energy consumption, and thus might adversely impact the environment in the long run. That is typical especially for less-developed countries, where urban economic development and population growth accelerate energy consumption substantially upward (Li et al., 2021).

As the present study thus reveals, a popular belief that "packing" cities with ICT tools can help generate positive environmental externalities and reduce intra–urban income inequality is apparently wrong. Therefore, to achieve a real improvement in environmental performance and to reduce urban inequality in cities, ICT tools that cities employ need to offer effective solutions to specific urban issues that a particular city faces (Katz & Bradley, 2013; Shelton et al., 2015), and to increase the efficiency of specific urban services that are identified as wasteful or inefficient (Bibri, 2019).

To facilitate the adoption of ICTs, it is also necessary to provide more equal access to such technologies for all population groups, including the elderly, lower–income population strata, and people with disabilities,

through community programs and bespoke training (Muriithi et al., 2016; Kassongo et al., 2018). Increased user confidence in ICTs can also be achieved through providing 24/7 technical support (Muriithi et al., 2016) and encouraging grassroot–level citizen initiatives aimed at environmental monitoring, interactive problem–reporting, and enabling online conferencing with the city management (Kassongo et al., 2018).

The smart city government might also involve initiatives that make professional training and education more affordable through municipal subsidies or grants for the underprivileged, especially for children from low–income families and people with disabilities (Coe et al., 2001; Garg et al., 2017). Thus, for example, the City of Chicago in the USA successfully launched an education municipal initiative, which builds a pipeline from high school to college, and applies this innovative through the Technology–Early–College–High–School Pathway (Klett & Wang, 2014).

Citizen participation is another objective, achieving which might help to reduce inequality and improve environmental performance of cities. As an example, the city of Namyangju in South Korea offers its residents an interactive participation platform that makes it possible to share information about local issues, by sending on–line reports to the city mayor and the city government (Myeong et al., 2020).

6 CONCLUSIONS

The present study demonstrates that reduction in income inequality and air pollution in cities is associated with several performance metrics, linked to innovativeness, smart government, and ecosystem vitality. Yet we find no evidence that the proliferation of Internet technologies and the number of universities the city hosts, i.e., popular ways of advancing "city smartness", are related to either intra–urban income disparity or environmental performance of cities per se. By way of empirical analysis, the present study also demonstrates that unless a specific ICTs feature, used to advance city smartness, is directly relevant to human welfare, such a feature is unlikely to contribute to city resilience and achieving environmental sustainability goals.

We thus recommend that transition of cities towards greater smartness should be focused on people's needs and skills in using ICTs, not on ICTs per se. This transition might include facilitating ICT access to all, including the elderly, lower–income population strata, and people with disabilities. Additional measures might include providing 24/7 technical support, enabling citizens to report urban problems in real–time, and encouraging grassroots–level citizen initiatives in environmental monitoring, by making such reporting options more accessible and affordable to all.

Several limitations of the present study analysis should be mentioned. First and foremost, as previously mentioned, we found no evidence of a significant association between either GINI, AQI, or UGC and several urban performance measures, such as e.g., the number of air quality monitoring stations and the number of wireless access points. This conclusion is based on the analysis of specific variables and may not necessarily be relevant to other SC indicators. Follow-up studies should thus attempt to analyze more SC performance measures, linking them to intra-urban income inequality, air quality, and other SC outcomes, using the analytical approach employed in this study or similar analytical tools. Such analyses would help to understand better which SC features actually foster population welfare, increase social resilience, and improve QoL in cities overall.

While the data we analyzed are fairly representative of different regions and reflect potential development confounders (such as, capital status, city area, etc.), the analysis covered only one year (2020) and involved 101 cities with available and comparable data. Further studies should thus attempt to expand the scope of the cities under analysis and the study's timeframe. Another important topic for future research is technological, economic, and environmental competencies of people living in SCs. Finding of such a study might help to foster urban competitiveness and improve QoL in cities overall.

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🏆 *reviewed paper*

Ein Ultraleichtflugzeug, Luftbilder, KI-Algorithmen und Geofach- und Geosachdaten – wie in Landsberg am Lech durch den Einsatz neuer Technologien ein digitaler Zwilling für die Stadt-, Klimaanpassungs- und Mobilitätsplanung aufgebaut wird

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1 ABSTRACT

Bei der Entwicklung umweltverträglicher Mobilität und der Erreichung gesetzter Klimaziele haben Kommunen einen erhöhten Informationsbedarf. Mit einer neuen Technologie werden kostengünstig ultrahoch aufgelöste Multisensor-Luftbilddaten erhoben, die neue Informationen für eine nachhaltige Stadt- und Verkehrsplanung liefern. Zur Datenanalyse werden neue KI-basierte Algorithmen entwickelt, um das Potenzial dieser neuen "big data" Datenquellen vollumfänglich nutzen zu können.

Ziel dieses Forschungsprojektes ist die raum-zeitliche Analyse flächendeckender Multisensor-Luftbilddaten und die Entwicklung eines realitätsnahen, virtuellen 3D-Modells, das die Grundlage zum Aufbau eines "digitalen Zwillings" darstellt. Durch die Anreicherung und Verschneidung mit kommunalen Geobasis- und Geofachdaten wird eine "TwinCity3D"-Plattform entwickelt, welche Planungsprozesse im städtischen und ländlichen Raum wesentlich verbessert. Verschiedene Szenarien der Stadt-, Klima- und Verkehrsplanung werden untersucht und Forschungsfragen beantwortet.

Mit Hilfe KI-basierter Algorithmen werden aus multitemporalen ultrahoch aufgelösten Luftbildern flächendeckend neue Informationen gewonnen. Dazu zählt die detaillierte Analyse des Stadtklimas über mehrere Jahre im Zusammenspiel von Verkehr, Bebauung und Stadtgrün sowie die Identifikation von Wärmeverlusten über Dachflächen. Die KI-basierte multitemporale Analyse des ruhenden Verkehrs im Stadtgebiet und Bilanzierung des Parkflächenverbrauchs liefert neue Informationen für eine künftige Mobilitätsplanung. Die Analyse und das Monitoring des Stadtgrüns führt zu neuen Erkenntnissen in Hinsicht auf Stadtklima und $_{CO2}$-Klimabilanz.

Die zu entwickelnde Datenanwendung wird Kommunen neue Informationen bereitstellen. Ein dreidimensionaler "digitaler Zwilling des Stadtgebietes" bietet weitreichende und neue Analysemöglichkeiten. Darüber hinaus wird die "TwinCity3D"-Plattform als innovatives Werkzeug für den Einsatz in öffentlichen Beteiligungsverfahren aufgebaut.

Keywords: Geodatenplattform, KI-Algorithmen, digitaler Zwilling, Luftbilder, Thermalaufnahmen

2 GRUNDLAGEN UND PROJEKTDESIGN

2.1 Ein Ultraleichtflugzeug und ein neu entwickeltes Kamerasystem

Im Rahmen des mFUND-Förderprojektes "TwinCity3D", welches im Sommer 2022 begonnen wurde und das eine Laufzeit bis Sommer 2025 hat, kommt das Ultraleichtflugzeug "Elektra One Solar" zum Einsatz, das von der Landsberger Firma Elektra Solar GmbH entwickelt wurde. Im Zuge des Vorgängerprojektes "ThermCity3D" wurde ein Kamerasystem entwickelt und verfeinert, das aus insgesamt fünf RGB-Kameras, einer Thermalkamera und einer Multispektralkamera besteht. Die gleichzeitige Anbringung der Kameraeinheiten ermöglicht die Erzeugung mehrerer Luftbildprodukte während eines einzigen Bildfluges.

Die Luftfahrzeugkategorie des Ultraleichtflugzeuges bietet sowohl gegenüber konventionellen Luftaufnahmen als auch gegenüber Drohnen Vorteile: Das Ultraleichtflugzeug kann auf einer Flughöhe von 300 m eingesetzt werden, auf diese Weise können mit den Kameras aus dem semiprofessionellen Bereich hochaufgelöste Luftbildprodukte erzeugt werden. Bei dem Luftraum um 300 m Höhe über Boden wird der Überflugbereich genutzt. Eine Einverständniserlaubnis einzelner Grundstückseigentümer oder Nutzungsberechtigte, wie sie beispielsweise beim Drohneneinsatz bis 120 m erforderlich wäre, kann beim Einsatz des Ultraleichtflugzeuges entfallen. Da die "Elektra One Solar" zudem auch elektrisch angetrieben

wird, reduzieren sich die antriebsbedingten Vibrationen auf ein Minimum und beeinflussen oder beeinträchtigen die Aufnahmequalität der montierten Kamerasystem nur wenig.

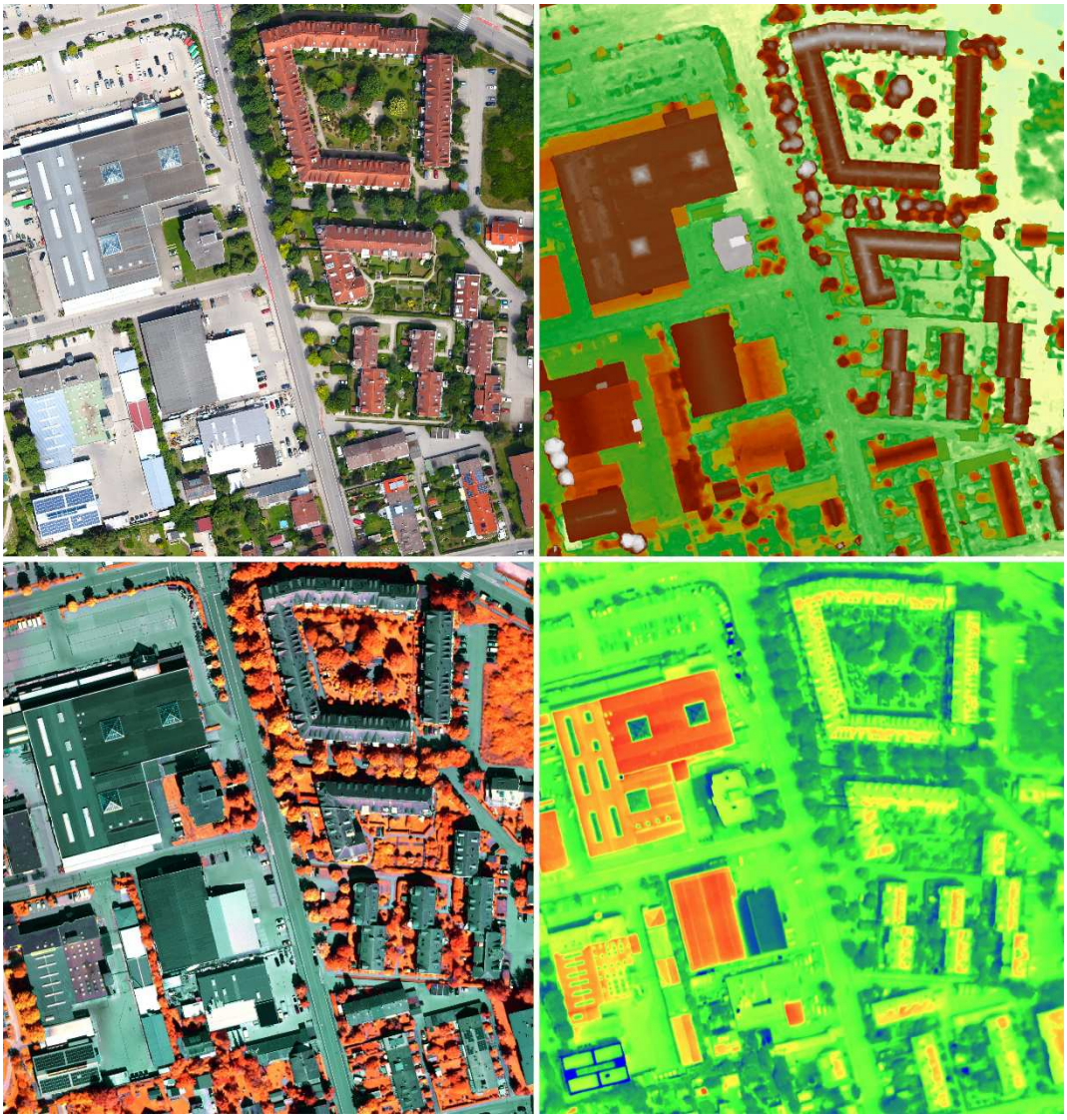

Abb. 1: Aus einem Bildflug können mehrere Luftbildprodukte erzeugt werden: RGB-True Orthofoto (links oben), Oberflächenmodell (rechts oben), Multispektralaufnahme (links unten), Thermalaufnahme (rechts unten) (3D RealityMaps 2022)

2.2 Luftbildprodukte und Befliegungsrhythmen

Für das Projekt TwinCity3D werden Aufnahmen des Stadtgebietes mit 5 cm Bodenauflösung erzeugt. Zwischen den Kriterien einer möglichst hohen Auflösung der Luftbildprodukte, einem sparsamen Umgang mit dem Akku des Ultraleichtflugzeugs und der zu erfassenden Gebietsausdehnung wurde so eine Kompromissentscheidung getroffen, die eine hohe Qualität der Neuerkenntnisse aus den Befliegungsdaten ermöglicht.

Die Befliegungen werden über die Projektlaufzeit von insgesamt drei Jahren mehrfach und zu unterschiedlichen Jahreszeiten durchgeführt. Auf diese Weise können in Abhängigkeit des Anwendungsfalls unterschiedliche Fragestellungen untersucht bzw. beantwortet werden. Nicht jedes Luftbildprodukt lässt Aussagen zu jedem Themenbereich zu. Die Thermalaufnahmen aus den Sommermonaten können beispielsweise zur Detektion von Verdachtsflächen etwaiger Hitzeinseln im Stadtgebiet verwendet werden und können in Kombination mit den Multispektralaufnahmen neue Erkenntnisse über den Gesundheitszustand von Stadtgrünstrukturen liefern. Die Ergebnisse der Winterbefliegung werden dagegen unter anderen Voraussetzungen verwendet. Im Rahmen der Pflichtaufgabe zur Erstellung einer kommunalen Wärmeleitplanung werden Analysen zur Annäherung des Wärmebedarfs innerhalb des Stadtgebietes getroffen. Die Thermalaufnahme in der Heizperiode kann hierzu Zusatzinfos beisteuern und so befasst sich

eine der gestellten experimentellen Forschungsfragen mit dem Ansatz, ob Wärmeverluste über Dachflächen erkannt und gegebenenfalls Annahmen zum Sanierungsstand von Gebäuden getroffen werden können.

2.3 Ein virtuelles Mesh-Modell des Stadtgebietes bildet die Grundlage für den digitalen Zwilling

Aufgrund unterschiedlicher äußerer Orientierungen, in diesem Fall Winkelpositionen, können die Luftbilder der fünf RGB-Kameras nach Abschluss des Bildfluges miteinander verrechnet werden. Im Zuge einer photogrammetrischen Berechnung kann das überflogene Stadtmodell als virtuelles 3D-Meshmodell gebildet werden. Das virtuelle 3D-Modell bildet die Basis zum Aufbau der TwinCity3D-Plattform. Das 3D-Modell allein besticht durch einen geringen Abstraktionsgrad und bildet das Stadtgebiet, sowie die grüne und blaue Infrastruktur realitätsnah ab. Die Orientierung und Navigation gelingt auch sogenannten “interessierten Laien”, d.h. Personen ohne explizite geographische oder planerische Ausbildung und Erfahrung im Kartenlesen, nach kurzer Einarbeitungszeit. Die Anwendung soll den Spieltrieb wecken und so können gemäß des Ansatz des “homo ludens” (STREICH 2011:217) planerische Inhalte auf spielerischem Wege platziert und durchaus ernste Themen kommuniziert, sowie politische Entscheidungen mit vorbereitet werden. Hierzu werden entsprechend der Forschungsfragen aus den verschiedenen Einsatzfeldern der zu entwickelnden TwinCity3D-Plattform zunehmend neue Ebenen designt und die Plattform fortentwickelt.

Abb. 2: Das virtuelle 3D-Meshmodell, erzeugt aus den RGB-Luftbildern (3D RealityMaps 2022)

2.4 Forschungsfragen

Für das Forschungsprojekt TwinCity3D wurden folgende Forschungsfragen formuliert, die im Laufe des Projektes bearbeitet werden:

(1) Kann die regelmäßige Befliegung zum Zwecke eines Klimamonitoring verwendet werden?

(2) Wie viele Fläche nimmt der oberirdisch ruhende Verkehr in Anspruch?

(3) Kann das Stadtgrün detailliert erfasst werden?

(4) Wie können Anwendungsszenarien in der Stadtplanung aussehen?

(5) Wie kann der digitale Zwilling bei der Kommunikationsarbeit der Stadtverwaltung unterstützen?

(6) Kann eine 3D-Visualisierung von Planungsszenarien die Transparenz und Beteiligung in Planungsprozessen verbessern?

(7) Welche Aspekte des Datenschutzes sind berührt und wie kann hiermit umgegangen werden?

3 BISHERIGE ANALYSEN – NEUE ERKENNTNISSE ÜBER DAS STADTGEBIET

3.1 Kommunale Wärmeleitplanung und Wärmebedarf im Stadtgebiet

Mit der kommunalen Wärmeleitplanung wurde die Planung der Wärmeversorgung innerhalb des kommunalen Gebietes zur Pflichtaufgabe. In den kommenden Jahren müssen sich alle deutschen Kommunen auf den Weg begeben, eine solche Wärmeleitplanung durchzuführen. Die einzelnen Schritte der kommunalen Wärmeleitplanung sind im Wärmeplanungsgesetz (WPG) festgelegt.

Der digitale Zwilling kann hierbei an verschiedenen Stellen unterstützend zum Einsatz kommen und Infos und neue Erkenntnisse über das Stadtgebiet ermöglichen. Einer der ersten Schritte, der im Rahmen dieser neuen Pflichtaufgabe zu bewältigen ist, ist die Abschätzung des Wärmebedarfes innerhalb des Stadtgebietes. Da in Fall von Landsberg am Lech keine flächendeckenden Informationen zu Gebäudebaujahren vorliegen und Informationen über zwischenzeitliche Sanierungen im Regelfall nicht in den Verwaltungsapparat eingehen, wird im Zuge der Ermittlung des Wärmebedarfes eine Analyse des Stadtgebietes vorgeschalten.

Zunächst wird ein stadtmorphologischer Ansatz gewählt, um die Entstehungsgeschichte des Stadtgebietes in zeitliche Epochen zu clustern. Dabei kommen einerseits historische Karten und Luftbilder zum Einsatz, andererseits werden die Ur-Bebauungspläne (spätere Änderungen innerhalb des gleichen Geltungsbereiches werden nicht berücksichtigt) der einzelnen Baugebiete dazu verwendet, um die Stadterweiterungen und Siedlungsentwicklungen abzubilden.

Die Cluster des Stadtgebietes werden hinsichtlich der Art der Flächennutzung in drei Klassen unterschieden:

- Wohnbauflächen
- Handel- und Gewerbeflächen
- Industrie- und Dienstleistungsflächen

Hierzu wird die vom Landesamt für Digitalisierung, Breitband und Vermessung (LDBV) bereitgestellte tatsächliche Nutzung verwendet und die Nutzungsklassen gefiltert. Anschließend werden Entstehungsgeschichte und Art der Nutzung miteinander verschnitten.

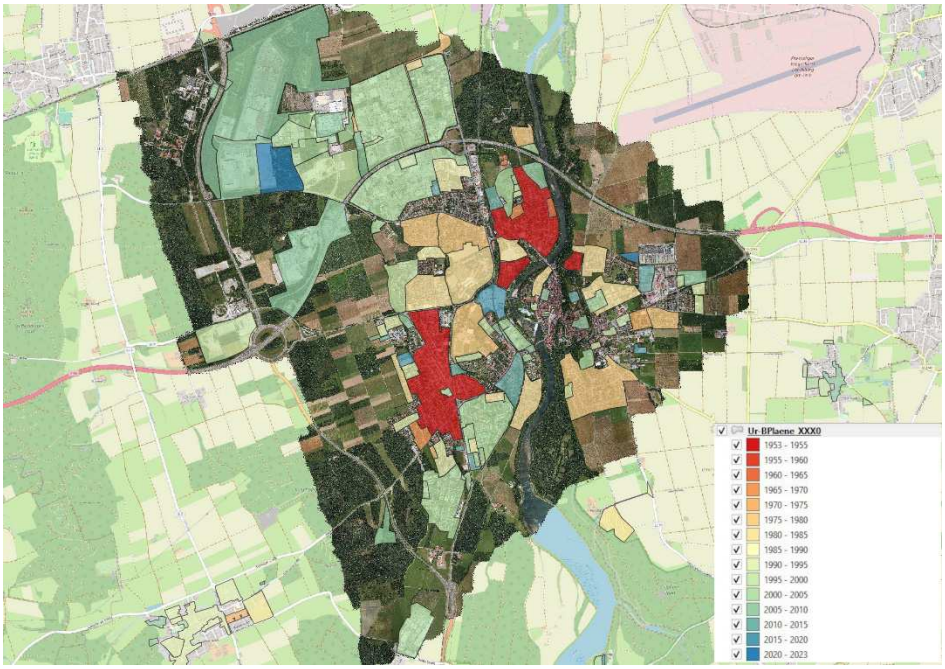

Abb. 3: Bebauungsplan-Analyse, Klassifizierung nach Datum der Rechtskraft (Stadt Landsberg am Lech 2024)

Um den Wärmebedarf abzuleiten, wird im Rahmen von TwinCity3D experimentell versucht, anhand der Gebäudefußabdrücke und des Volumens eine überschlägige Berechnung anzustellen. Im Zuge der kommunalen Wärmeleitplanung ist es im Weiteren erforderlich, Versorgungsgebiete zu identifizieren, diese räumlich abzugrenzen und Angebote der Art der Wärmeversorgung zuzuordnen. Auf diese Weise entsteht ein flächenfüllendes Mosaikgebilde über das Stadtgebiet, welches dieses in die vier Versorgungsklassen

- Wärmenetzgebiete

- Wasserstoffnetzgebiete
- Gebiete mit dezentraler Wärmeversorgung und
- Prüfgebiete

einteilt und Versorgerinnen, Versorgern, Planerinnen, Planern, Nutzerinnen und Nutzern eine Auskunft und mehr Planungssicherheit geben soll.

3.2 Erkenntnisse aus der durchgeführten Winterbefliegung

Die Luftbildprodukte aus der Befliegung während der Heizperiode liefern neue Erkenntnisse, die im Zuge der kommunalen Wärmeleitplanung eingespielt werden können. Die nachfolgende Abbildung zeigt die RGB-Aufnahme zweier benachbarter Baugebiete unterschiedlichen Entstehungsjahrzehnts und die Überlagerung der RGB-Aufnahme mit den Temperaturen auf den Dachoberflächen.

Abb. 4: RGB-Orthofoto aus dem Winter-Bildflug (links) und Überlagerung der Temperaturen an der Dachoberfläche (rechts) (RealityMaps 2023)

Während auf den östlich gelegenen Gebäuden der Schnee auf den Dachflächen zum Teil bereits geschmolzen ist, liegt der Schnee auf den Gebäuden im westlichen Bildausschnitt noch flächig. Die Überlagerung mit der Thermalaufnahme kann zur Verifizierung dieses Erstverdachtes eingesetzt werden. Die Zahlen belegen, was bei der Ansicht der RGB-Aufnahme mit Schneebelag vermutet wurde: Auf den Dachflächen östlich kann eine höhere Oberflächentemperatur gemessen werden, als diese auf den westlichen Dachflächen festgesetellt werden kann. In diesem Stil können mehrere Bildausschnitte im Stadtgebiet identifiziert werden und dieses Beispiel zeigt zugleich, dass bereits die qualitative Interpretation eines RGB-Bildes Verdachtsflächen zu etwaigen Wärmeverlusten über Dachflächen zulassen kann. Beim Vergleich der Bauvolumina fällt auf, dass die Außenmaße der betrachteten Gebäude ähnliche Dimensionen aufweisen. Ein reiner Vergleich von Bauvolumina liefert für die kommunale Wärmeleitplanung nur einen theoretischen Wärmebedarf. Die Analyse des Stadtgebietes nach etwaigen Auffälligkeiten hinsichtlich Wärmeverluste über den Dachflächen, kann die Datenlage des Wärmebedarfes für die kommunale Wärmeleitplanung konkretisieren und Erkenntnisse zur späteren Dimensionierung von Versorgungsgebieten und Planung der Versorgungsinfrastruktur beitragen.

Die Auswertung der Temperaturverteilung auf den Dachoberflächen unter Berücksichtigung des Bebauungsplanjahrgangs zeigt auf, dass insbesondere bei Gebäuden älteren Baujahres, höhere Temperaturen festgestellt werden können. Das arithmetische Mittel aller analysierten Dachoberflächentemperaturen der Thermalaufnahme aus der Winterbefliegung beträgt -4° Celsius. Auf 10,5 % bzw. 168 Dachoberflächen der Gebäude aus rechtskräftigen Bebauungsplänen vor 1980 wurden Temperaturen über dem arithmetischen Mittel festgestellt.

Aus dem Gebäudebestand, der auf Basis von Bebauungspläne aus den Jahren 2010 bis 2020 entstanden ist, weisen dagegen lediglich 3 % bzw. 4 Dachoberflächen Temperaturen oberhalb des aritmethischen Mittels von -4° Celsius auf.

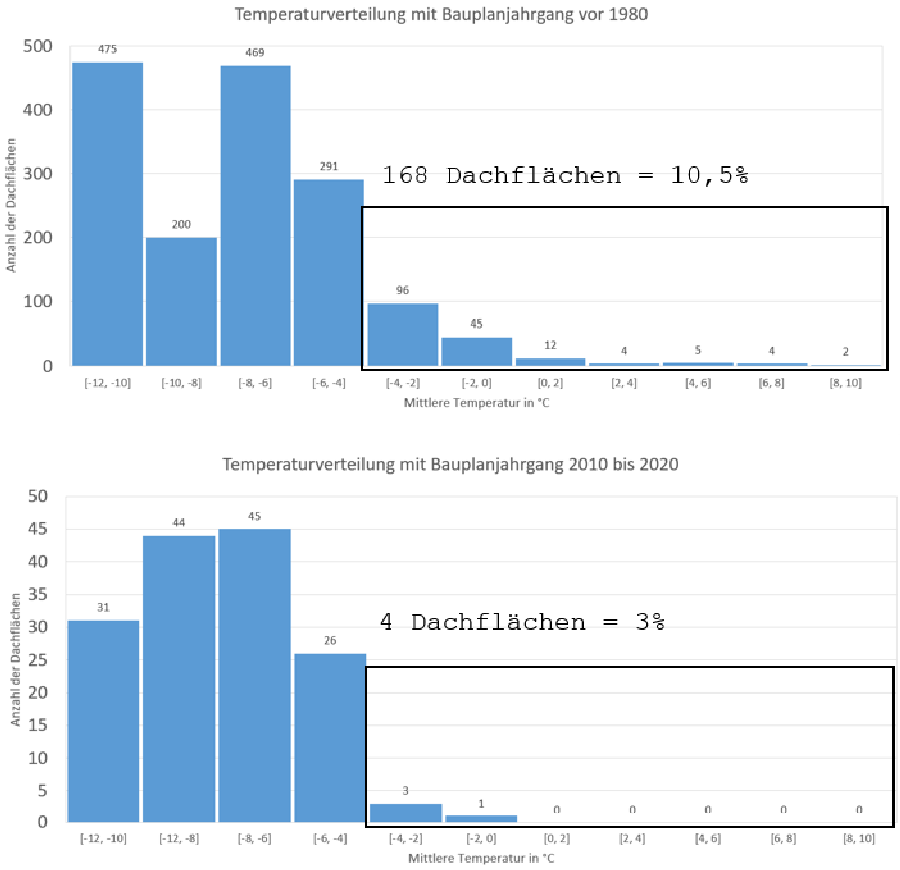

Abb. 5: Temperaturverteilung mit Bebauungsplanjahrgang (RealityMaps 2023)

Bei der Fokussierung auf die Dachoberflächen von Industriegebäuden können aufgrund der großflächigen Dachstrukturen auch Detailaussagen getroffen werden. Das nachfolgende Beispiel zeigt konkrete Wärmeverluste über Teildachflächen auf.

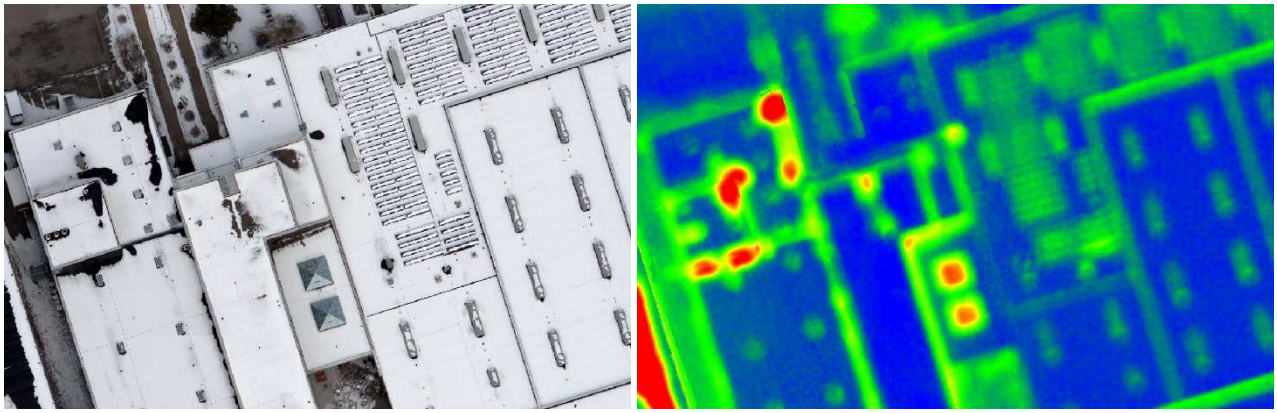

Abb. 6: Bei der vergleichenden Betrachtung der Dachflächen von Industriegebäuden anhand von RGB-Luftbild und Thermalaufnahme aus den Wintermonaten können Wärmeverluste identifiziert werden (RealityMaps 2023)

3.3 Einsatzmöglichkeiten bei der Energieversorgung – PV-Potenzial

Die Dachflächen des Stadtgebietes spielen bei einem weiteren Anwendungsfall für den digitalen Zwilling eine Hauptrolle: Sie verbergen ein Ausbaupotenzial für Photovoltaik- und Solaranlagen und somit zur Förderung der Nutzung erneuerbarer Energien.

Die TwinCity3D-Plattform wird als Hybridstruktur aufgebaut und integriert neben dem fotorealistischen Meshmodell den vom LDBV bereitgestellten LOD2-Datensatz. Der LOD2-Datensatz bildet bei der Ermittlung des PV-Potenzials die Basis für den ersten Schritt der Analyse. Die Dachstrukturen des gesamten Stadtgebietes werden nach ihrer Ausrichtung klassifiziert und bilanziert.

Abb. 7: Auf Basis des virtuellen 3D-Stadtmodells ermitteltes PV-Potenzial, klassifiziert nach Dachausrichtungen (RealityMaps 2023)

Mittels trainierter KI-Algorithmen werden in den nächsten Analyseschritten Restriktionen ermittelt, die von den Gesamtdachfläche zu subtrahieren sind. Aus dem 3D-Meshmodell werden Dachteilflächen wie Gauben berechnet, die aufgrund ihrer Größe nur bedingt oder nicht zur Installation von PV-Anlagen geeignet sind. Aus den Luftbildprodukten der Sommerbefliegung (und somit keiner Beeinträchtigung durch Schnee) werden in einem weiteren Schritt die bereits installierten PV-Anlagen erkannt und bilanziert.

Die Flächenanalyse im GIS ermöglicht somit die Bilanzierung von Ausnutzungsgrad und dient dem Aufzeigen bisher ungenutzter PV-Potenziale. Da die Befliegung multitemporal, d.h. in regelmäßigen Abständen erfolgt, kann ein Monitoring über den Fortschritt des PV-Ausnutzungsgrades erzeugt werden. Der Vergleich der Luftbilder aus verschiedenen Jahren zeigt auf, wo Veränderungen stattgefunden haben und wo zwischenzeitlich PV-Anlagen errichtet wurden. Die erneute Durchführung der beschriebenen Analysen mittels Anwendung von KI-Algorithmen und Flächenbilanzierung im GIS erzeugt ein PV-Ausbaumonitoring und kann beispielsweise im Rahmen der Jahresberichterstattung des Klimaschutzreferates im politischen Gremium verwendet werden.

3.4 Stadtgrünstrukturen klassifizieren und die Anreicherung des Baumkatasters

Stadtgrünstrukturen nehmen eine bedeutende Rolle für das Mikroklima ein und können im Sinne der Umsetzung des Schwammstadtprinzips einen Beitrag als Retentionsflächen leisten. Um die Resilienz im Stadtgebiet zu fördern, können die Instrumente eines Entwicklungsplans für das Stadtgrün sowie ein Stadtgrünmonitoring unterstützend eingesetzt werden. Bevor es soweit ist und Maßnahmen abgeleitet warden können, ist jedoch zunächst eine umfangreiche Datenerhebung erforderlich.

Die Führung eines Baumkatasters gehört insbesondere aus Verkehrssicherungspflicht zu den städtischen Aufgaben. Inhalt des städtischen Baumkatsters ist die Erfassung derjenigen Bäume, die auf oder unmittelbar angrenzend an öffentlichen Wege- und Verkehrsflächen stehen. Informationen zu den Baumbeständen auf privaten Grundstücken und den Flächen der Forstverwaltung gehören nicht zu den Regelaufgaben des Baumkatasters. Für die Zwecke der Klimaanpassungsplanung sind weiterführende Informationen erforderlich. Aus diesem Grund wird im Rahmen von TwinCity3D ein Algorithmus zur Detektion von Bäumen fortentwickelt. Der KI-Algorithmus liefert einerseits den Stammmittelpunkt jeden Baumes > 2 Meter, andererseits auch den Kronendurchmesser sowie eine Typenunterscheidung in Laub- und Nadelbaum. Aus dem Oberflächenmodell werden die Höheninformationen mit einer Genauigkeit von +/- 1 Meter abgeleitet. Durch die Kombination dieser Informationen wird es zukünftig möglich sein, Annäherungen zum städtischen Grünvolumen, der Biomasse und schlussendlich der Speicherkapazitäten von Kohlenstoff innerhalb des Stadtgebietes berechnen und in einer Gesamtbilanz festhalten zu können.

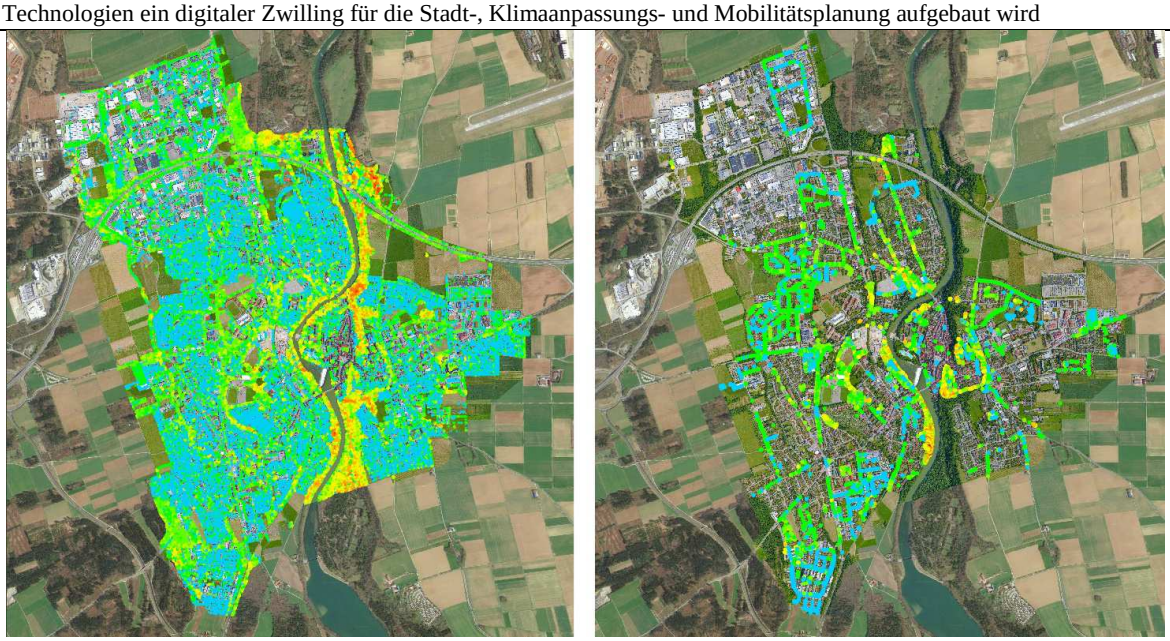

Abb. 8: Per KI-Algorithmus erkannte Bäume (links) vs. im Baumkataster kartierte Bäume (rechts) (RealityMaps 2024)

Gegenüber dem städtischen Baumkataster, innerhalb dessen 7.024 Bäume regelmäßig kontrolliert und kartiert werden, wurden durch die Verwendung des KI-Algorithmus 41.883 Bäume automatisch erkannt und in Höhenklassen zugeordnet. Die Klassifikationsgenauigkeit liegt dabei bei > 94 %.

Der Vergleich der Luftbildinformationen aus verschiedenen Befliegungsdaten dient der Differenzanalyse, zwischenzeitlicher Aufwuchs oder entfernte Grünstrukturen können dokumentiert und im Sinne eines Stadtgrünmonitorings Veränderungen festgehalten werden.

4 DER PROTOTYP DER TWINCITY3D-PLATTFORM

4.1 Layerstruktur

Das jeweils aktuellste 3D-Mesh-Modell aus den Befliegungsdaten stellt die Grundlage der „TwinCity3D“-Plattform dar. Es dient als Navigationsebene und ermöglicht aufgrund des niedrigen Abstraktionsgrades finden sich auch sogenannte „interessierte Laien“ schnell zurecht und können sich innerhalb des Modells orientieren, weil bekannte Situationen schnell wiedererkannt werden. Zusätzlich lassen sich auf dieser ersten Ebene der TwinCity3D-Plattform Punktinformationen abrufen. Aufgrund der Kombination von Geokoordinaten und verknüpfter Datenbank mit Zusatzinformationen lassen sich Points-of-Interest an den Stellen im virtuellen 3D-Stadtmodell wiederfinden, wo sie sich in der Realität zuordnen lassen.

Im Kapitel weiter oben, in dem auf die PV-Potentialanalyse eingegangen wird, wurde bereits die Anlegung der TwinCity3D-Plattform in Hybridstruktur erwähnt. Das vom LDBV bereitgestellte CityGML-Modell des Gebäudedatensatzes im Level-of-Detail-2 (LOD2), d.h. als Blockmodell mit Standarddachformen (KOLBE 2008:3) kann als weitere Visualisierungsebene eingeblendet werden. Die mittels angewandtem KI-Algorithmus ermittelten Baumbestände können durch vereinfachte Darstellung in Höhe und Kronendurchmesser hinzugeschalten und gemäß den Zuständigkeiten der städtischen Amtsstruktur in „Stadtgrün“ oder „Forstgrün“ unterschieden werden.

3D-Meshmodell und CityGML-Modell stellen unterschiedliche „Welten“ dar, die jeweils unterschiedliche Vor- und Nachteile bieten und je nach Anwendungsfall mit weiteren Geosach- und Geofachdaten angereichert werden können. Da das 3D-Meshmodell aufgrund des niedrigeren Abstraktionsgrades höhere visuelle Ansprüche erfüllt, eignet es sich besonders zur Navigation oder Anreicherung mit weiteren Themen, die schnell und korrekt zugeordent werden müssen. Das CityGML-Modell weist einen wesentlich höheren Abstraktionsgrad auf und kann für Simulationen verwendet werden, die einen modellhaften Charakter aufweisen. Beispielsweise wurde in den aktuellen Prototypen der TwinCity3D-Plattform bereits eine Schattensimulation integriert, bei der Datum und Tageszeit eingestellt und die Auswirkungen des Schlagschattenverlaufes im Modell visualisiert werden können.

Die integrierte Funktion der „Split-Screen“-Ansicht vereint die beiden Welten schließlich wieder anhand eines dynamischen Schiebereglers, bei dem innerhalb des gewählten Bildausschnittes zwischen Mesh- und CityGML-Modell dynamisch gewechselt werden kann. Auf diese Weise kann eine parallele Navigation im fotorealistischen 3D-Meshmodell und im 3D-CityGML erfolgen, was wiederum den Vorteil einer schnellen Standort-Zuordnung des gerade im CityGML gezeigten Simulationsergebnisses erlaubt.

Zusätzliche Ergebnisse von GIS-Analysen können als 2D-Kartenebene überblendet werden. Aktuell sind erste Heatmaps mit Thermalinformationen, Baumdichten oder Infos zum oberirdisch ruhenden Verkehr verfügbar. Auch hier werden die Vorteile der Navigation im virtuellen 3D-Meshmodell ausgespielt: Durch die halbtransparente Überblendung können auch Laien eine unmittelbare Verknüpfung der zu transportierenden geostatistischen Info mit der räumlichen Situation herstellen.

Abb. 9: Benutzeroberfläche des TwinCity3D-Plattform-Prototypen (RealityMaps 2024)

Im weiteren Verlauf des Forschungsprojektes ist vorgesehen, die TwinCity3D-Plattform um Importmöglichkeiten zu erweitern. So soll es zukünftig möglich sein, dass Mitarbeitende der Stadtverwaltung selbst Punkt-, Linien- und Flächeninformationen im Shape-Format zu integrieren. Um die Beurteilung von 3D-Informationen, wie beispielsweise Bauvorhaben, besser beurteilen zu können, ist zusätzlich eine Importfunktion für 3D-Inhalte vorgesehen. Die TwinCity3D-Plattform erweitert damit den digitalen Werkzeugkasten der Stadtverwaltung und soll bei der Kommunikationsarbeit von Sachverhalten im Alltag unterstützen.

Gerade bei den 3D-Aspekten verspricht sich das Forschungsteam einen Mehrwert durch die Ausspielung des niedrigen Abstraktionsgrades: Die Herausforderung der Transferleistung, die gezeigten Inhalte gedanklich mit der gebauten Realität zu verknüpfen, wird erleichtert. Gegenüber der Verwendung von gerenderten Einzelperspektiven oder zweidimensionalen Plänen kann in der TwinCity3D-Plattform der Standort frei gewählt und Planungsalternativen diskutiert werden. Auf diese Weise wird die Idee der „Echtzeitplanung“ (ZEILE 2010) aufgegriffen und fortentwickelt. Die Beurteilung eines geplanten Bauvorhabens im Hinblick auf räumliche Dimension, Wirkung und Einfügen wird transparenter und trägt so ingesamt zu einer Verbesserung der Planungs-Kommunikation bei (STREICH 1996).

4.2 Datenschutzaspekte

Der Datenschutz wird bereits in der ersten Projektphase berücksichtigt. Mit 5 Zentimetern ist die Bodenauflösung der als Basis erzeugten Luftbilder so gewählt, dass beispielsweise Persone als solche erkannt werden können, eine Identifikation jedoch nicht möglich ist. Nummernschilder oder ähnliche personenbezogene Informationen können ebenfalls nicht identifiziert werden. Die Luftbilder liefern somit keine personenbezogenen Informationen. Verknüpfungen zu personenbezogenen aus Geosachdatenbanken, wie beispielsweise Eigentumsverhältnisse, sind im Rahmen des Forschungsprojektes nicht vorgesehen.

Die Definition der Nutzerinnen- und Nutzergruppen der sich im Aufbau befindenden „TwinCity3D“-Plattform wurde im ersten Projektjahr vorgenommen. Aus diesen Angaben lassen sich Nutzungsansprüche und Verwendungsmöglichkeiten bestimmen und in der Folge Anforderungen ableiten. Die Stadtverwaltung übernimmt dabei die Aufgabe der Datenaktualisierung, der Auswertung eingehender Informationen und bereitet Analyseergebnisse für politische Gremien oder Beteiligungsveranstaltungen vor. Die „Vollversion“ der „TwinCity3D“-Plattform wird deshalb zukünftig der Stadtverwaltung zugesprochen.

Informationen die bedenkenlos und ohne vertiefenden Erklärungsbedarf öffentlich zugänglich gemacht werden können, wird eine öffentliche Version der „TwinCity3D“-Plattform entwickelt. Diese Version soll ohne Login- bzw. Passwortschutz bereitgestellt werden.

Zwischen diesen beiden Extremen ergeben sich noch vielfältige Anwendungsfälle, für die maßgeschneiderte Lösungen erforderlich werden können. Über ein Layerrechtemanagement sollen zukünftig auch Zwischenversionen entstehen können, so dass auch einzelne Layer aus der Vollversion zugetielt werden können, um beispielsweise Varianten eines Bauvorhabens, in Form von virtuellen 3D-Modellen, diskutieren zu können und politische Entscheidungen herbeizuführen. Gleiches gilt im Rahmen der Vorbereitung von Beteiligungsverfahren wie sie aus der Bauleitplanung bekannt sind. Eine Importmöglichkeit für XPlanGML-Datensätze wird vorbereitet und kann zukünftig unterstützend zum Einsatz kommen.

5 FAZIT UND AUSBLICK

Nach gut der Hälfte der Projektlaufzeit wurden in “TwinCity3D” einige Meilensteine bereits erreicht. Datenschutzrechtliche Aspekte wurden frühzeitig bearbeitet, eine strategische Strukturierung gemäß der zukünftigen potenziellen Nutzergruppen definiert, erste Befliegungen durchgeführt und die Luftbildprodukte sowie KI-Algorithmen fortentwickelt und analysiert. Hieraus sind neue Erkenntnisse über das Stadtgebiet von Landsberg am Lech entstanden, die in den Anwendungsbereichen des Klimaschutzes, der Klimaanpassungsplanung, sowie dem Stadtgrünmanagement Verwendung finden werden. Für den weiteren Projektverlauf stehen noch einige Meilensteine aus, über die die aktuell noch prototypisch vorliegende TwinCity3D-Plattform zunehmend fortentwickelt und verfeinert wird. Das spätere Produkt soll es auch Klein- und Mittelstädten ohne umfassende Smart City-Strategie ermöglichen, kostengünstig Mehrwerte aus diesem Bereich mittels neuer Technologien zu erzeugen. Eine Wegeentscheidung zwischen 3D-Meshmodell oder 3D-CityGML-Ansatz ist aus Sicht des Projektteams zukünftig nicht mehr zwingend erforderlich, da eher das Beste aus beiden 3D-Welten genutzt und zusammengeführt werden sollte.

6 DANKSAGUNG, FÖRDERHINWEIS

Der vorliegende Beitrag entstand im Zuge des darin vorgestellten Forschungsvorhabens “TwinCity3D – Entwicklung einer geodatenbasierten “TwinCity3D”-Plattform und KI-Analysetools zur Unterstützung einer umweltfreundlichen Stadt- und Verkehrsplanung”, welches im Rahmen der Innovationsinitiative mFUND des BMDV gefördert wird. Die Autoren bedanken sich beim mFUND und dem BMDV für die Förderung und beim TÜV Rheinland für die inhaltliche und organisatorische Unterstützung.

Über den mFUND des BMDV: Im Rahmen der Innovationsinitiative mFUND fördert das BMDV seit 2016 datenbasierte Forschungs- und Entwicklungsprojekte für die digitale und vernetzte Mobilität 4.0. Die Projektförderung wird ergänzt durch eine aktive fachliche Vernetzung zwischen Akteuren aus Politik, Wirtschaft, Verwaltung und Forschung und durch die Bereitstellung von offenen Daten auf dem Portal mCLOUD. Weitere Information finden Sie unter www.mFUND.de

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Emotionen im Radverkehr messen, vergleichen und verstehen: Evaluation verschiedener Erhebungsansätze in der Stadt Osnabrück

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1 ABSTRACT

In der Diskussion um die Mobilitätswende nehmen aktive Mobilitätsformen, darunter insbesondere der Radverkehr, im urbanen Kontext eine Schlüsselrolle ein. In der Praxis hemmt die vielerorts nur als mangelhaft empfundene Sicherheit mitunter jedoch potenzielle Nutzerinnen und Nutzer in ihrer Entscheidung, das Fahrrad für ihre alltäglichen Wegstrecken zu nutzen (BMDV, 2022). Darüber hinaus sind auch bei sogenannten Alltagsradfahrenden immer häufiger Effekte, wie beispielsweise die Inkaufnahme massiver Umwege (CYCLINGDATA, 2023), zu beobachten, die in direktem Zusammenhang mit einem subjektiv empfundenen Mangel an Sicherheit und Komfort gebracht werden können. Wie aber können diese Emotionen von Radfahrenden für die Planung entschlüsselt werden und dabei helfen, neuralgische Punkte im städtischen Radverkehrsnetz zu identifizieren?

Mit unter anderem diesen Fragestellungen beschäftigt sich das im Rahmen des mFUND-Programms des BMDV[1] geförderte Verbundprojekt „Emotion Sensing für (E-)Fahrradsicherheit und Mobilitätskomfort“, kurz „ESSEM“. Mithilfe iterativer statistischer und sensorischer Erhebungen von umfeld- und personenbezogenen Daten analysiert das Projekt neuralgische Stresspunkte im kommunalen Radverkehrsnetz der Partnerstadt Osnabrück.[2] Die gewonnenen Erkenntnisse sollen übergeordnet dabei helfen, Methoden und Handlungsempfehlungen für eine moderne, datengestützte Radverkehrsplanung zu entwickeln, um das Radfahren im urbanen Kontext zukünftig angenehmer und sicherer zu gestalten.

Der vorliegende Beitrag setzt den Fokus auf den Vergleich verschiedenerErhebungsansätze, die im Rahmen der ESSEM-Messkampagnen in der Stadt Osnabrück erprobt wurden. In diesem Zusammenhang werden sowohl die gesammelten Ergebnisse aus den als Freifahrten konzipierten Erhebungsphasender vergangenen zwei Jahre, als auch die Ergebnisse der erst kürzlich durchgeführten Kontrollstudie mit einer vorgegebener Route miteinander in Beziehung gesetzt. Zum einen wird damit das Ziel verfolgt, etwaige Störfaktoren zu identifizieren und im Aufbau zukünftiger Erhebungen eliminieren zu können. Zum anderen zielt der direkte Vergleich der Ergebnisse darauf ab, erste Hypothesen zu Einfluss nehmenden Stressfaktoren und vulnerablen Personengruppen abzuleiten.

Keywords: citizen science, urban stress, Stadtplanung, Radverkehrsplanung, Emotion Sensing

2 EINLEITUNG

Neben einigen Informationen zum Themenkomplex Sicherheitsempfinden beim Fahrradfahren werden nachfolgend noch die Rahmenparameter des vom BMDV geförderten ESSEM-Projekt erläutert sowie die sich ergebenden Forschungsfragen präsentiert.

2.1 Hintergründe

In Bezug auf die Planung der ökologisch, räumlich und sozial nachhaltigen und gerechten Stadt der Zukunft gewinnen aktive Mobilitätsformen zunehmend an Bedeutung. Damit ist jedoch nicht nur das Thema Verkehr gemeint, sondern vor allem auch die Notwendigkeit, den Menschen und seine spezifische Wahrnehmung wieder verstärkt in den Mittelpunkt urbaner Planungen zu rücken. Insbesondere im Bereich der aktiven Mobilität, wie z.B. dem Radfahren, sind die Menschen ihrer Umwelt nämlich sehr unmittelbar ausgesetzt. Wie die Menschen bei ihrer Bewegung durch die Stadt ihre Umgebung wahrnehmen und wie sicher sie sich

[1] Bundesministerium für Digitales und Verkehr
[2] Siehe (ZEILE et al., 2023 & HAUG et al., 2023) für detailliertere Informationen zu den Methoden des Projekts und der Fahrradinfrastruktur Osnabrücks.

subjektiv dabei fühlen, kann deshalb auch direkte Auswirkungen darauf haben, ob sie sich für oder gegen ein Verkehrsmittel entscheiden (JOHANNSEN, 2013).

In der Praxis hemmt die vielerorts nur als mangelhaft empfundene Sicherheit im urbanen Stadtverkehr mitunter potenzielle Nutzerinnen und Nutzer erheblich in ihrer Entscheidung, das Fahrrad für ihre alltäglichen Wegstrecken zu nutzen (BMDV, 2022). Darüber hinaus sind auch bei sogenannten Alltagsradfahrenden immer häufiger Effekte, wie beispielsweise die Inkaufnahme massiver Umwege (CYCLINGDATA, 2023), zu beobachten, die in direktem Zusammenhang mit einem subjektiv empfundenen Mangel an Sicherheit und Komfort gebracht werden können. Aus diesen Gründen muss der Implementierung von Wahrnehmungen und Emotionen der Nutzerinnen und Nutzer der aktiven Mobilität in die kommunale Planung zukünftig eine Schlüsselrolle beizumessen.

2.2 Das BMDV-Projekt ESSEM

Das vom Bundesministerium für Digitales und Verkehr geförderte „Emotion Sensing für (E-) Fahrradsicherheit und Mobilitätskomfort“, kurz: „ESSEM”, beschäftigt sich aus dieser Notwendigkeit heraus seit dem Jahr 2022 mit der Erforschung von Stress beim Radfahren. Das ESSEM-Projekt findet in den Modellstädten Osnabrück und Ludwigsburg statt. Die vorliegende Studie konzentriert sich auf die Ergebnisse der Untersuchung in Osnabrück.

Die im Rahmen des Projekts zum Einsatz kommende Methodik erprobt dabei zum einen die sensorische Erhebung körperbezogener Daten beim Radfahren, die auch als „EmoCycling-Methode” bekannt ist. Die erhobenen biostatistischen Daten geben gemeinsam mit der geografischen Position dann Aufschluss über die erlebten Stresssituationen während der Fahrradnutzung. Die gesammelten Daten dienen damit der Identifikation neuralgischer Punkte im urbanen Radwegenetz. Die zweite Säule der im Projekt angewendeten Methodik bilden standardisierte Fragebögen, die Aufschluss über das Verkehrsverhalten und persönliche Dispositionen der Probandinnen und Probanden liefern. Die Daten aus den Fragebögen ergänzen die Daten aus den EmoCycling-Messungen und ermöglichen eine weitere Differenzierung in verschiedene Stress-vulnerable Gruppen.

Detailliertere Ausführungen zum Projektablauf, den Methoden und der untersuchten Fahrradinfrastruktur Osnabrücks sind in den Arbeiten von Zeile (ZEILE et al., 2023) und Haug (HAUG et al., 2023) zu finden.

2.3 Forschungsfragen

Das ESSEM-Projekt beschäftigt sich im Kontext der Modellstadt Osnabrück mit den folgenden Fragestellungen:

(1) Wo fühlen sich Radfahrende in Osnabrück gestresst?

(2) Inwieweit beeinflussen sowohl Umweltfaktoren, als auch persönliche Dispositionen wie Alter, Geschlecht oder Persönlichkeit dabei das subjektive Stressempfinden?

(3) Mithilfe welches Settings können Störfaktoren eliminiert und die erhobenen Daten objektiv vergleichbar gemacht werden?

3 STAND DER FORSCHUNG

Der hier vorgestellte Stand der Forschung fokusiert sich auf die grundsätzlichen Ansätze gängiger Stresstheorien, die Dimensionen des Sicherheitsempfindens, verschiedene Radfahrtypen und ihre Merkmale, sowie die Methodik zum Identifizieren und Lokalisieren von Stress.

3.1 Das Phänomen Stress

Grundsätzlich unterscheiden sich Stresstheorien hauptsächlich in ihrer Anpassungsfähigkeit und Operationalisierbarkeit. Stress entsteht immer dann, wenn, je nach theoretischer Untermauerung, die Physis (Stress als Reaktion) oder die Psyche (Stress als Reiz oder Stress als Transaktion) Ressourcen zur Verarbeitung von Umweltreizen aufbringen muss.

Das in diesem Kontext bekannteste Modell ist das transaktionale Stressmodell nach Lazarus (LAZARURS, 1999). Gleichzeitig ist dieser Ansatz aber auch am komplexesten, da in diesem Modell Stress immer situativ in der Interaktion von Mensch und Umwelt entsteht. Darüber hinaus sind Stress-als-Reaktion-Modelle (SELYE, 1956; CANNON, 1932) gängig, die die körperlichen Reaktionen auf einen externen Stimulus

untersuchen (BERCHT, 2013). Entscheidend ist hier die Annahme, dass ein Stimulus alle Menschen gleichermaßen „stresst“ (LYON, 2005). Die dritte Gruppe von Ansätzen zur Stresstheorie, konzentriert sich auf die psychologischen Auswirkungen und versteht Stress als Stimulus. Hier wird davon ausgegangen, dass es „kritische Lebensereignisse“ (HOLMES & RAHE, 1967) gibt, die in gewissem Maße objektiv Stress auslösen.

Aufgrund der vielfältigen Entwicklungen in der Emotionsforschung auf diesem Gebiet entspricht die stresstheoretische Grundlage der vorliegenden Arbeit zum Großteil den Modellen aus der Stress-als-Reaktion-Perspektive. Dennoch werden ergänzend auch subjektive Komponenten in die Datenerhebung und -analyse einbezogen.

3.2 Sicherheitsempfinden & Radfahrtypen

Der folgende Abschnitt erläutert zunächst die verschiedenen Dimensionen von Sicherheit und die damit verbundenen Einflussfaktoren. Darauf aufbauend wird anschließend eine gängige Kategorisierung von Radfahrenden in verschiedene Typen vorgestellt, die im Rahmen des ESSEM-Projekts sowohl für die Zielgruppenauswahl, als auch für die Datenauswertung eine Schlüsselrolle einnimmt.

3.2.1 Dimensionen des Sicherheitsempfindens & Einflussfaktoren

Das Sicherheitsempfinden spielt bei der Wahl des Verkehrsmittels eine wichtige Rolle und setzt sich aus einer objektiven und einer subjektiven Dimension zusammen. Die objektive Sicherheit kann in diesem Zusammenhang relativ einfach mithilfe von Statistiken, wie zum Beispiel der polizeilichen Unfallstatistik, quantifiziert werden. Die subjektive Dimension des Sicherheitsempfindens hingegen, wird von einer Vielzahl an Faktoren bestimmt. Bei der Erforschung von Stressphänomenen und deren schädlichen Auswirkungen auf den menschlichen Körper ist es nämlich vor allem relevant, wie stark die jeweilige Person den erlebten Stress bewertet und damit auch empfindet. Für die Wahl des Verkehrsmittels ist diese subjektive Dimension von Sicherheit daher entscheidend und nimmt in der Radverkehrsförderung eine Schlüsselrolle ein (JOHANNSEN, 2013).

Im Kontext der Untersuchung des subjektiven Sicherheitsempfindens sind dabei zunächst „exogene“ Faktoren, also externe strukturelle Faktoren, zu nennen. Diese können zu kritischen Situationen, Beinahe-Unfällen, einem Gefühl der Bedrängung oder einer lärminduzierten Stressreaktion führen. Der daraus resultierende Stress beim Radfahren kann daher die Entscheidung für das Radfahren negativ beeinflussen und ist daher ein wichtiger Ansatzpunktpunkt in der Radverkehrsforschung (GRAF, 2016).

Zusätzlich zu diesen „exogenen Faktoren” beeinflussen auch verschiedene persönliche Dispositionen, „endogene Faktoren“, das subjektive Sicherheitsempfinden. Diese beziehen sich auf individuelle demographische, sozioökonomische und soziokulturelle Merkmale von Individuen und ihrem sozialen Umfeld, die die Wahrnehmung maßgeblich beeinflussen (WERMUTH, 2005). Beispiele für relevante Faktoren sind Geschlecht, Alter, körperliche Konstitution, Ortskenntnisse oder Vertrautheit mit dem Verkehrsmittel. Darüber hinaus gibt es aus biopsychologischer Sicht Hinweise darauf, dass genetische oder psychische Prädispositionen Stressreaktionen verstärken oder abschwächen können. In diesem Zusammenhang nehmen Persönlichkeit, Kontrollüberzeugungen und Risikotoleranz eine besondere Rolle ein (SCHANDRY, 2016; KOVALEVA, 2012).

3.2.2 Radfahrtypen und Merkmale

Im Kontext des Radfahrens lassen sich anhand einiger dieser Faktoren sowie der Hinzunahme des spezifischen Radfahrverhaltens verschiedene Nutzergruppen kategorisieren. Nach Geller ergeben sich daraus vier Gruppen (GELLER, 2009): „die Starken und Furchtlosen“, „die Begeisterten und Souveränen“, „die Interessierten aber Besorgten“ und „Keine Chance, ganz egal wie“ (siehe Tabelle 1).

Die Zugehörigkeit zu einer dieser Gruppen kann sich – je nach Veränderung des Mobilitätsverhaltens und Lebenssituation – dynamisch verändern und ist bei manchen Personen nicht eindeutig zuzuordnen. Nichtsdestotrotz bietet die Einteilung in die vier Gruppen einen wichtigen Anhaltspunkt, um die Fähigkeiten, Wünsche und Bedürfnisse der verschiedenen Radfahrtypen analysieren zu können. In Hinblick auf die Förderung des Radverkehrs ist vor allem die Gruppe der „Interessierten, aber Besorgten” eine wichtige Zielgruppe, da diese im Allgemeinen zwar gegenüber dem Fahrradfahren aufgeschlossen sind, jedoch

bezüglich ihrer Sicherheit besorgt sind und das Fahrrad deshalb (noch) nicht für ihre täglichen Fahrten verwenden.

Radfahrgruppe	**Die Starken und Furchtlosen (furchtlose Radfahrende)**	**Die Begeisterten und Souveränen (Alltagsradfahrende)**	**Die Interessierten aber Besorgten (Interessierte Radfahrende)**	**Keine Chance, ganz egal wie!**
Eigenschaften	Nutzt das Fahrrad immer, sicher und souverän	Fährt täglich Strecken mit dem Fahrrad, souverän aber mittleres Sicherheitsbedürfnis	Keine Alltagsmobilität mit dem Fahrrad; besorgt bezüglich der Sicherheit, aber dem Fahrrad gegenüber aufgeschlossen	In der Regel keine Fahrradnutzung
Fahrkönnen	Ausgezeichnete Beherrschung des Fahrrades	Selbstbewusst, teilweise defensiv wegen Sicherheit	Weniger souverän	Schlechte Kontrolle über das Fahrrad, fehlende Fahrpraxis
Stresstoleranz	Hoch	Mittel	Niedrig	Sehr niedrig

Tabelle 1: Eigenschaften der Radverkehrsgruppen nach Geller. (Quelle: Eigene Darstellung nach Geller, 2009)

3.3 Identifizieren und Lokalisieren von Stress

Das Messen von „Stress“ als eine Reaktionen des Autonomen Nervensystems ist mittlerweile technisch möglich. Gleichwohl müssen dabei einige theoretische Einschränkungen in Kauf genommen werden. Im Allgemeinen werden zur Ermittlung von Stressmomenten, den „Moments of Stress“, kurz: „MOS“, physiologische Indikatoren verwendet. In diesem Zusammenhang reagiert der menschliche Organismus unmittelbar nach der Konfrontation mit einem Stressor, in dem er endogene Stressreaktionen reguliert, um wieder in ein körperliches Gleichgewicht, die Homöostase, herzustellen. Diese Reaktionen lassen sich durch eine Vielzahl von körpereigenen Parametern nachweisen und sind als bewährte Methode zur Messung von Stress durch externe Stressoren anerkannt. Dazu gehören ein Anstieg der elektrodermalen Aktivität (EDA) und ein Rückgang der Hauttemperatur (KYRIAKOU et al., 2019; SCHANDRY, 2016). Mithilfe des Algorithmus von Kyriakou et al. aus der Urban Emotions Inititative (KYRIAKOU et al., 2019) können die MOS von Menschen mithilfe von tragbaren Biosensoren erkannt werden.

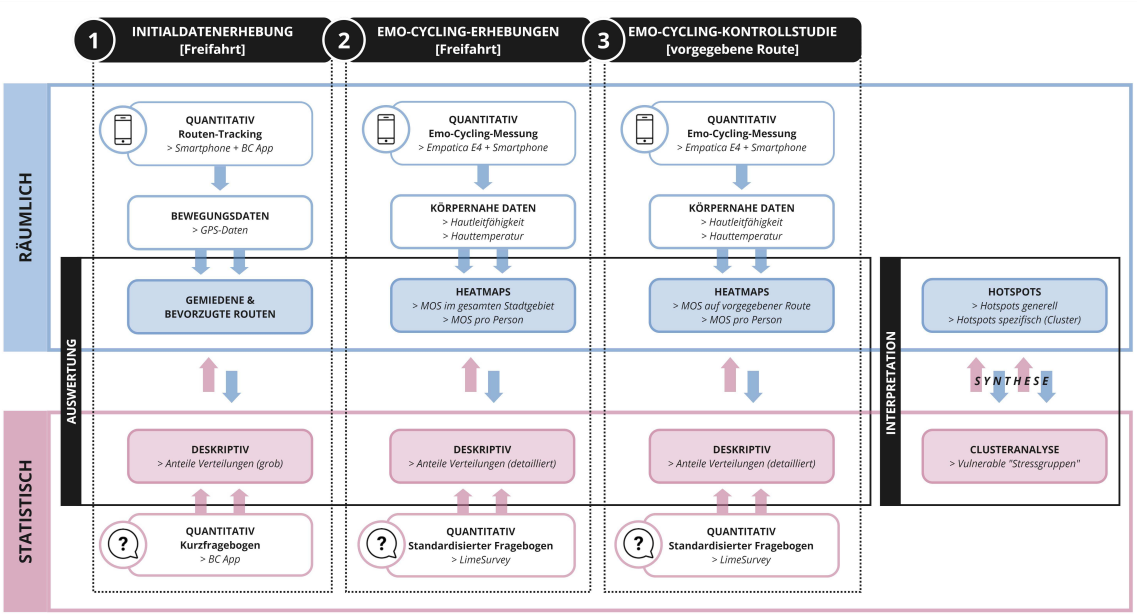

Abbildung 1: Triangulationsschema der angewendeten Methodenbausteine.

Das Ergebnis ist eine maschinenlesbare Datei im CSV-Format, in der eine Zeile einer Sekunde des Messzeitraums entspricht. Darin enthalten sind Informationen über einen MOS (ja/nein) und seine

geografischen Koordinaten. Die Daten werden in der Auswertung dann in einem Geografischen Informationssystem (GIS) eingelesen und einer Kernel-Dichte-Schätzung (KDE) unterzogen, um räumliche Cluster zu ermitteln. Umgangssprachlich wird diese Visualisierung der gemessenen Stressreaktionen in der Stadt aus als „Heatmap“ bezeichnet.

Das Verfahren, biostatistische Daten georeferenziert zu erfassen und anschließend in Karten zu visualisieren, geht dabei auf Christian Nold zurück (NOLD, 2009). Seine „emotionale Kartographie“ ermöglichte es erstmals, den Menschen und seine individuelle physiologische Reaktion erstmals als eine Art Sensor zu nutzen und seinen Stress- bzw. Erregungszustand im urbanen Kontext zu erfassen. Verschiedene technologische Entwicklungen in diesem Kontext, sowie die Weiterentwicklung der Technologie selbst werden im Kontext des Radfahrens seither als „EmoCycling-Methode“ (ZEILE et al., 2016) zusammengefasst. Das Setting besteht seither aus dem Biosensorarmband „E4“ der Firma Empatica uns einem Smartphone, das mittels der App „E-Diary“ die Daten sammelt und georeferenziert.

Zur Erforschung des Stressempfindens von Radfahrern wird im Rahmen des Projekts ESSEM ein Triangulationsverfahren (FLICK, 2011) eingesetzt. Bei dieser Methode können die Nachteile einer Methode durch die Hinzunahme einer anderen während der Untersuchung kompensiert werden. Abbildung 1 zeigt einen Überblick der Methodenbausteine und den in ESSEM angewendeten Triangulationsprozess. Die Triangulation wurde für die Datenerhebung, die Analyse (räumlich und statistisch) und deren Interpretation verwendet. Die einzelnen Bausteine werden in den folgenden Abschnitten genauer erläutert.

3.4 Initialdatenerhebung

3.4.1 Durchführung

Die Initialdatenerhebung wurde im Frühling 2022 in einer frühen Phase des ESSEM-Projekts durchgeführt. Die Daten bilden die Grundlage für die ab Herbst 2022 durchgeführten EmoCycling-Messungen. Mit dieser ersten Datenerhebung wurde das Ziel verfolgt, einen Überblick über die Bewegungsprofile von Radfahrenden in Osnabrück zu gewinnen. Dabei wurden die Nutzerinnen und Nutzer der aktiven Fahrrad-Community Bike Citizens direkt über die gleichnamige App als Probandinnen und Probanden angesprochen. Nach Einwilligung der Nutzerinnen und Nutzer, am Projekt teilzunehmen, wurde mithilfe der App dann aufgezeichnet, welche Routen die rund 350 Probandinnen und Probanden in Osnabrück für ihre alltäglichen Fahrten mit dem Fahrrad nutzen.

3.4.2 Ergebnisse

Mithilfe der von Bike Citizens entwickelten Analysefunktionnen konnten daraufhin verschiedene fahrradverkehrsspezifische Beobachtungen abgeleitet und in entsprechenden Analysekarten dargestellt werden. Abbildung 2 zeigt zwei Attraktivitätsanalysen, die sich als besonders erkenntnisreich für das Projekt erwiesen haben. Auf der linken Seite ist das Hauptwegenetz (gelb) im Zusammenhang mit den von den Radfahrenden bevorzugten Routen (grün) abgebildet. Auf der rechten Seite wird das Wegenetz wiederum mit den gemiedenen Routen (rot) überlagert. Die Linienstärke gibt in den Karten die Intensität an.

Auffallend in Osnabrück ist allgemein die intensive Nutzung der Wege in das Stadtzentrum. Im westlichen Bereich sind es dabei vor allem die als Fahrradstraße markierte Katharinenstraße und die überwiegend auf Tempo 30 beschränkten Straßen des Stadtteils Wüste (1), die von den Radfahrenden bevorzugt wurden. Gemieden werden hingegen die unmittelbar parallel zur Katharinenstraße verlaufende, vom MIV geprägte Martinistraße im Süden (2) und die Lotter Straße im Norden. Auch der südwestliche Innenstadtring wird von den Radfahrenden gemieden. Im Süden in Kalkhügel wird die Sutthauser Straße zugunsten des Burenkamp umfahren. Im Südosten ziehen die teilnehmenden Radfahrenden die Meller Straße der vierspurigen Hannoverschen Straße vor.

Desweiteren lassen sich anhand der beiden Karten auch auf der Hauptverkehrsachse des Wallrings, die das Stadtzentrum umringt, Auffälligkeiten beobachten. Während hier der nordwestliche Abschnitt des Wallrings (3) eine oft gewählte Route darstellt, wurde der südliche Abschnitt (4) von den Radfahrenden tendenziell häufiger gemieden.

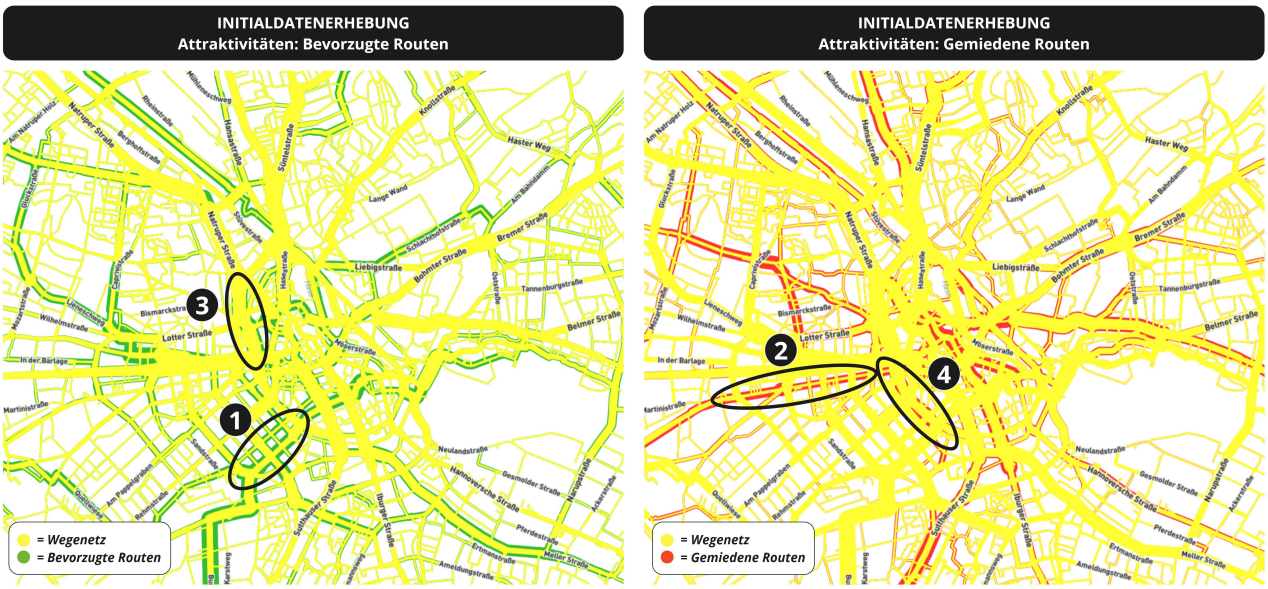

Abb. 2: Initialdatenerhebung in Osnabrück. Attraktivitätsanalyse: Bevorzugte Routen (links) und Gemiedene Routen (rechts). (Quelle: Eigene Darstellung nach Bike Citizens Analytics, 2022)

3.5 Befragungen

Über den gesamten Erhebungszeitraum des Projekts ESSEM wurden die räumlichen Datenerhebungen jeweils mit statistischen Erhebungen kombiniert, die in Form von Befragungen durchgeführt wurden (siehe Abbildung 1).

3.5.1 Kurzbefragungen (Initialdatenerhebung)

Im Zuge der Initialdatenerhebung wurden die Probandinnen und Probandenneben der Aufzeichnung ihrer alltäglichen Fahrradfahrten in Osnabrück ebenfalls dazu aufgefordert, einen kurzen Fragebogen in der Bike Citizens App zu beantworten. Die gesammelten Daten dienten dem Projekt dazu, einen ersten Überblick über das Nutzerverhalten der Radfahrenden in Osnabrück zu gewinnen und geeignete Personengruppen für die EmoCycling-Datenerhebungen zu identifizieren.

3.5.2 Standardisierte Fragebögen (EmoCycling-Datenerhebungen)

Auch die durchgeführten EmoCycling-Erhebungen wurden jeweils um standardisierte Fragebögen ergänzt. In diesem Zusammenhang war es das Ziel, weitere Informationen über die Probandinnen und Probanden zu erhalten, die Aufschluss über deren spezifisches Mobilitätsverhalten und persönliche Dispositionen geben. Im weiteren Projektverlauf werden diese Informationen dann in Zusammenhang mit den gemessenen Stressmomenten gesetzt. Perspektivisch soll es mithilfe dieser Analyse ermöglicht werden, vulnerable Gruppen in Hinblick auf das Stressempfinden zu identifizieren.

Der entwickelte Fragebogen ist dabei über die Plattform LimeSurvey zugänglich, mithilfe derer nach einem automatisierten Prozess in kurzer Zeit erste statistische Auswertungen generiert werden können. Die Dateneingabe der Probandinnen und Probanden erfolgt anonymisiert. Um eine Verknüpfung der Fragebogendaten mit den Ergebnissen der sensorgestützten Messung zu ermöglichen, wird den Teilnehmenden während des Fragebogens empfohlen, ein Pseudonym zu erstellen. Dies trägt dazu bei, ihre Anonymität zu wahren.Damit die Fragebogendaten im Anschluss mit den Daten der sensorgestützten Messung in Zusammenhang gebracht werden können, werden die Teilnehmenden im Verlauf des Fragebogens dazu aufgefordert, ein Pseudonym generieren. Durch diese Methode wird die Anonymität der Datensätze gewährleistet.

Die Erkenntnisse aus den Fragebögen dienen darüber hinaus dazu, eine möglichst repräsentative Stichprobe für die EmoCycling-Datenerhebungen zu ziehen. Um die Teilnehmenden darüber zu informieren, ob sie als Probandinnen und Probanden für die Messungen ausgewählt wurden, haben die Teilnehmenden am Ende des Fragebogens deshalb die Möglichkeit, auf freiwilliger Basis ihre Emailadresse als Kontaktmöglichkeit anzugeben.

3.6 EmoCycling-Datenerhebung Phasen 1-4 als Freifahrt

3.6.1 Durchführung

Ab dem Herbst 2022 wurde dann mit der mehrphasigen Durchführung der EmoCycling-Datenerhebungen in Osnabrück begonnen. Bei diesen als Freifahrten konzipierten Messungen wurden die physiologischen Stressreaktionen der Probandinnen und Probanden nach der EmoCycling-Methode aufgezeichnet, ausgewertet und in Form einer Heatmap kartiert (vgl. Kapitel 3.3).

In jeder Erhebungsphase wurden dabei rund 30 Probandinnen und Probanden für jeweils zwei Wochen mit den Messinstrumenten ausgestattet. Eine Teilnahme an mehreren Erhebungsphasen war dabei möglich. Insgesamt konnten dadurch 89 Probandinnen und Probanden akquiriert werden. Durch Mehrfachteilnahme ergaben sich 116 Testfahrende. Die Gesamtfahrtzeit betrug im Rahmen der Erhebungen rund 914 Stunden. In der Auswertung konnten dabei 53796 Stressmomente detektiert werden.

Die Teilnehmenden der Freifahrten waren im Durchschnitt 47 Jahre alt. Zudem identifizieren sich jeweils 42% als weiblich bzw. männlich, 1% als divers und 14% machten keine Angabe.

Die meisten Teilnehmenden sind Alltagsradfahrenden (59%), 21% sind der Gruppe der Interessierten Radfahrenden zuzurechnen und 7% fallen unter die Kategorie der furchtlosen Radfahrenden. Es gab keine „Keine Chance, ganz egal wie!“ (vgl. Tab.2).

3.6.2 Ergebnisse

In Abbildung 3 sind die gesammelten Ergebnisse aller Erehbungsphasen in Osnabrück zu sehen. Auf der linken Karte sind dabei die von den Probandinnen und Probanden gewählten Routen gemappt. Die rechte Karte visualisiert die gesammelten Ergebnisse der Stressmessungen als Heatmap. Die besonders auffälligen Stress-Hotspots sind in der Heatmap markiert und werden im Folgenden benannt.

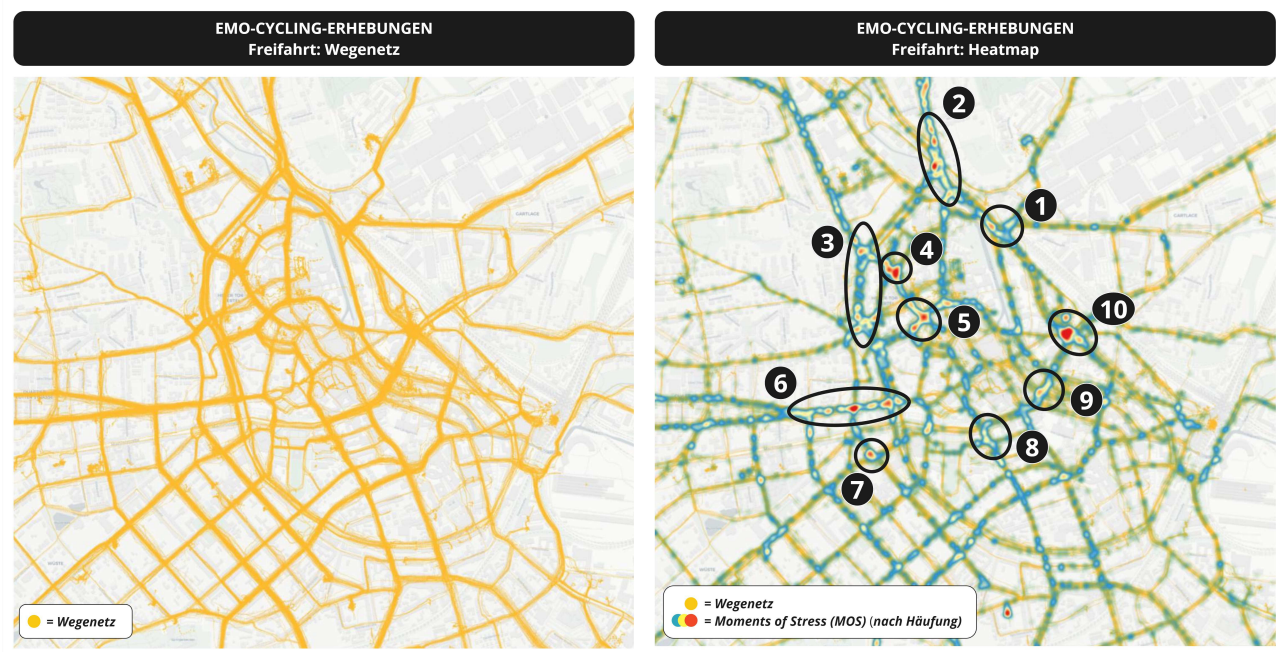

Abb. 3: EmoCycling-Datenerhebungen in Osnabrück: Ausschnitte des Wegenetzes aller Testfahrten (links) und der Heatmap der detektierten Stressmomente mit Markierung auffälliger Bereiche (rechts).

Dabei fallen zum einen die beiden Stress-Hotspots an den nördlichen Stadteingängen ins Auge. Sowohl der Nonnenpfad (1), als auch die Hansastraße (2) sind in diesem Kontext Hauptverbindungswege auf den Wallring, wobei sich deren Kreuzungspunkte jeweils auch unmittelbar unter den Bahngleisen befinden.

Desweiteren konnten entlang des nordwestlichen Teils des Wallrings (3) eine Vielzahl an Stressmomenten nachgewiesen werden. Neben dem Stress-Hotspot am Hegertor, ist auch hier insbesondere auf die Kreuzungspunkte der Stadteingänge mit dem Wallring hinzuweisen. Im Norden ist diesbezüglich vor allem die Natruper Straße und im Westen die Martinistraße (6) auffällig.

Im Kern des Stadtzentrums zeigen sich im Rahmen der Messungen sowohl die scharfe Kurve der Bierstraße (4), als auch die Dielingerstraße (5) als Stress-Hotspots.

Jenseits des Wallrings sind zudem die Kreuzungspunkte zwischen Heinrichstraße und Schnatgang (7), der Bereich an der Universität (8), sowie die Wittekindstraße (9) in der Nähe des Neumarkts als auffällige Stress-Hotspots zu erkennen. Im Osten des Stadtzentrums konnte darüber hinaus auch die große Straßenkreuzung am Berliner Platz (10) als ein neuralgischer Punkt im Radverkehrsnetz der Stadt Osnabrück identifiziert werden.

3.6.3 Limitationen

Anhand der Visualisierung der gesammelten Messergebnisse konnten im Rahmen der Auswertung einige neuralgische Punkte im Wegenetz der Stadt Osnabrück als Stress-Hotspots identifiziert werden. In diesem Kontext muss jedoch konstatiert werden, dass aufgrund des besonderen Forschungsdesigns der EmoCycling-Erhebungen als Freifahrten nicht alle Routen des Wegenetzes während des Erhebungszeitraums gleichmäßig befahren wurden. Einige Routen wurden von den Probandinnen und Probanden so zum Beispiel nur sehr selten, beziehungsweise überhaupt nicht, gewählt. Andere Abschnitte wurden hingegen eindeutig präferiert. In der logischen Konsequenz bedeutet das für die Auswertung der Heatmap, dass die Wahl der Fahrtstrecke unmittelbar mit der Belastbarkeit der Messergebnisse steht. Für einige Routen können mit den angeführten Messungen deshalb zwar belastbare Aussagen getroffen werden, für andere Streckenabschnitte ist in diesem Kontext die Stichprobenanzahl jedoch zu gering.

Weiterhin sind die Messergebnisse nicht nur hinsichtlich der freien der Streckenwahl, sondern auch in Bezug auf die verschiedenen Tageszeiten in ihrer Aussagekraft einzugrenzen. In diesem Zusammenhang konnte anhand einzelner Datensätze die Hypothese aufgestellt werden, dass entlang bestimmter Routen zu den Stoßzeiten ein deutlich höheres Stresslevel gemessen werden konnte, als an anderen Tageszeiten.

Im Rahmen des ESSEM-Projekts sollen die als Freifahrt durchgeführten EmoCycling-Messungen deshalb in einem nächsten Schritt mithilfe einer Kontrollstudie auf einer vorgegebenen Route evaluiert werden. Mit dieser Studie sollen einerseits die identifizierten Hotspots verifiziert und dabei durch die einheitliche Route uns Tageszeit eine Vergleichbarkeit der Ergebnisse gesichert werden. Darüber hinaus soll mit der Kontrollstudie jedoch auch der Fragestellung nachgegangen werden, ob zusätzlich zu den genannten Stress-Hotspots noch weitere neuralgische Abschnitte identifiziert werden können, die im Rahmen der Freifahrten von den Probandinnen und Probanden nicht befahren, beziehungsweise eventuell sogar gemieden wurden.

3.7 EmoCycling-Kontrollstudie mit vorgegebener Route

3.7.1 Durchführung

Ende November 2023 wurde dann die Kontrollstudie durchgeführt, mithilfe derer die Ergebnisse der bereits durchgeführten EmoCycling-Messungen evaluiert und ergänzt werden sollten. Für die Kontrollstudie wurde aus den Erkenntnissen der vorherigen Freifahrten eine Route entwickelt, auf der alle Probanden an einem Tag auf den Parcours geschickt wurden. Die Routenvorgabe wurde dabei im Vorfeld sowohl unter Berücksichtigung der identifizierten Stress-Hotspots und gemiedenen Streckenabschnitte, als auch der aktuell von Seiten der Stadt Osnabrück umgesetzten Verbesserungsmaßnahmen für den Radverkehr konzipiert. Die Stress-Hotspots aus den Freifahrten, die mit der Kontrollstudie verifiziert werden sollten, sind in Abbildung 4 als „Fixpunkte“ markiert. Für die Kontrollstudie wurden aus den bereits durchgeführten EmoCycling-Erhebungen Probandinnen und Probanden akquiriert, deren Durchschnittsalter Mitte 40 betrug. Bei der Auswahl der Probandinnen und Probanden wurde darüber hinaus auch auf eine gleichmäßige Geschlechterverteilung geachtet. Die Messungen fanden an einem Freitag Nachmittag statt, sodass ein möglichst gleichmäßiges Verkehrsaufkommen und eine ausreichende Helligkeit garantiert werden konnte. Die Teilnehmenden wurden hierfür erneut mit den Sensoren Empatica E4 und einem Smartphone ausgestattet und über den Verlauf der Strecke unterrichtet.

Insgesamt konnten für die Durchführung der Kontrollstudie 21 Probandinnen und Probanden akquiriert werden. Die durchschnittliche Fahrtzeit betrug auf der Vorgegebenen Route rund 30 Minuten. Im Rahmen der Auswertung konnten in diesem Zusammenhang 1452 Stressmomente detektiert werden. Die Gesamtmesszeit betrug dabei in Summe rund 14 Stunden.

In der Kontrollstudie lag der Altersdurchschnitt mit 50,2 Jahren leicht über dem der Freifahrten. Auch haben mehr Männer (62%) als Frauen teilgenommen. Der Großteil (86%) sind Alltagsradfahrende, 14 % Interessierte Radfahrende. Tabelle 2 stellt die Verteilungen gegenüber.

Die Zusammensetzung der Stichprobe der Kontrollstudie ist somit nicht repräsentativ für die Grundgesamtheit der Freifahrten. Die Verzerrungen bei Alter, Gender und Radfahrtyp sind bei der Interpretation der Ergebnisse zu berücksichtigen.

Übersicht Stichproben Osnabrück		
Merkmal	**Freifahrten (n=89)**	**Kontrollstudie (n=21)**
Alter in Jahren (⌀)	47	50,2
Gender (%)		
Weiblich	42	38
Männlich	42	62
Divers	1	0
Keine Angabe	14	0
Radfahrtyp (%)		
Kann nicht, will nicht	0	0
Interessierte Radfahrende	21	14
Alltagsradfahrende	59	86
Furchtlose Radfahrende	7	0

Tabelle 2: Verteilung der Merkmale in den Erhebungsrunden in Osnabrück. Eigene Berechnungen.

3.7.2 Ergebnisse

Abbildung 4 zeigt die Konzeption der Kontrollstudie, sowie das Ergebnis der EmoCycling-Messungen. Die linke Karte bildet dabei die Konzeption der Teststrecke ab. Dabei wurden die neuralgischen Punkte aus der Freifahrt als Fixpunkte in rosa markiert.

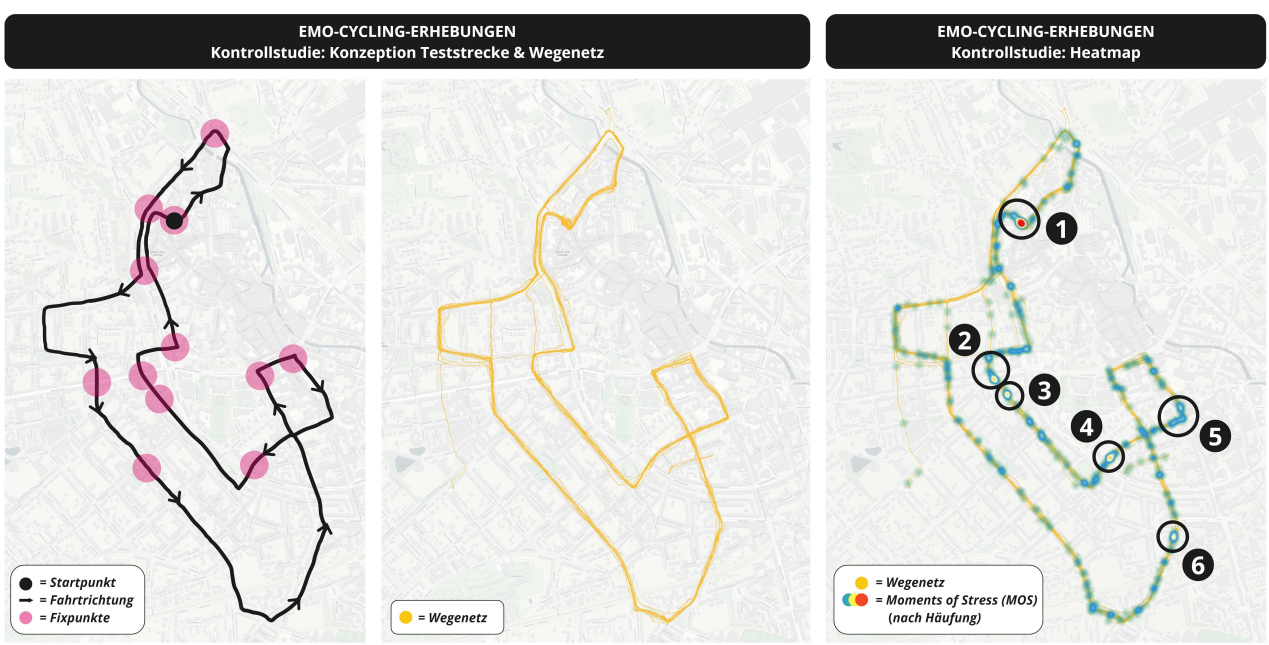

Abb. 4: EmoCycling-Kontrollstudie in Osnabrück: Konzeption der Teststrecke (links), Wegenetz (Mitte) und Heatmap der detektierten Stressmomente mit Markierung auffälliger Bereiche (rechts).

Die Karte in der Mitte zeigt die gefahrene Strecke, wobei die Probanden an manchen Stellen aufgrund von Orientierungsproblemen minimal von der vorgegebenen Teststrecke abgewichen wurde. Der Großteil der gesammelten Tracks bewegte sich dabei jedoch auf der korrekten Route, sodass die fehlerhaften Abschnitte nicht zu sehr ins Gewicht fallen. Die rechte Karte visualisiert die gesammelten Ergebnisse der

Stressmessungen als Heatmap. Die Heatmap wurde mithilfe einer KDE mit den Parametern r=40 m und max=21 erstellt.

Die besonders auffälligen Stress-Hotspots wurden auch in dieser Heatmap markiert und werden im Folgenden im Vergleich mit den Ergebnissen aus den Freifahrten betrachtet. In diesem Zusammenhang konnten einige der gesetzten Strecken-Fixpunkte, die sich bei den Freifahrten als stressintensiv zeigten, mit der Kontrollstudie verifiziert werden. So wurden die scharfe Kurve an der Bierstraße (1), die Kreuzungspunkte der Martinistraße (2), die Situation am Schnatgang (3), sowie die Süsterstraße (4) im Bereich des Wallrings und an ihrem Kreuzungspunkt zur Johannisstraße (5) mithilfe der Kontrollstudie als neuralgische Punkte bestätigt. Darüber hinaus konnten im Rahmen der Kontrollstudie auch neue Stresspunkte identifiziert werden. So zum Beispiel der Kreuzungspunkt an der mehrspurigen, MIV-geprägten Sutthauser Straße (6), die jedoch bereits in der Initialdatenerhebung als gemiedene Routen analysiert wurde.

4 DISKUSSION

Der vorgestellte Ansatz zeigt anhand der EmoCycling-Methode auf, unter welchen verschiedenen Settings Emotionen von Radfahrenden im urbanen Kontext messbar gemacht werden können. Dabei können sowohl beim Aufbau der Messungen als Freifahrt, als auch mit einer vorgegebenen Route, einige Vor- und Nachteile festgestellt werden, die im Folgenden diskutiert werden.

Als ein deutlicher Vorteil der Freifahrten hat es sich insbesondere erwiesen, dass die Testfahrten der Probanden sehr nutzerfreundlich und alltagsnah gestaltet werden konnten. Die Heatmaps stellen dadurch nicht nur einen guten Gesamtüberblick sicher, sondern liefern darüber hinaus auch Informationen zu den Nutzungsintensitäten verschiedener Streckenabschnitte. Dieser Vorteil ist jedoch zugleich auch als Nachteil zu bemängeln (vgl. Abschnitt 4.3.3). Denn die Messreihe des vorliegenden Projekts zeigt in diesem Kontext auch, dass trotz der verhältnismäßig hohen Teilnehmendenzahl einige Streckenabschnitte nicht, beziehungsweise nur sehr selten, befahren wurden. In der Konsequenz lässt sich für diese Streckenabschnitte deshalb keine belastbare Aussage zum subjektiven Stressempfinden der Probanden treffen.

Durch die Vorgabe der Route konnte diese Schwachstelle im Rahmen der Kontrollstudie jedoch nahezu vollständig eliminiert werden. Der Vergleich der Ergebnisse beider Methodensettings (vgl. 4.4.2) zeigt darüber hinaus, dass eine Evaluierung erster Hypothesen zu Stress-Hotspots mithilfe einer vorgegebenen Route sinnvoll erscheint. Um schließlich jedoch eine belastbare Verifizierung der Hotspots vornehmen zu können, müsste die Stichprobenzahl der Kontrollstudie in einem nächsten Schritt noch erhöht werden.

5 AUSBLICK

Die räumlichen Erhebungen des ESSEM-Projekts in der Modellstadt Osnabrück sind abgeschlossen. Ergänzend zu den räumlichen Analyse wird sich das Projekt nun in der nächsten Phase intensiv mit der statistischen Analyse der Daten aus den Fragebögen und der Rückkopplung mit den Heatmaps beschäftigen. Mithilfe statistischer Gruppenvergleiche und Clusteranalysen (Schmidt-Hamburger, 2022) sollen dadurch erste Hypothesen zu vulnerablen Stressgruppen getroffen werden können. Die Ergebnisse dieser Analyse sollen im Sommer 2024 vorliegen.

Gleichzeitig wird anhand der identifizierten Stress-Hotspots derzeit durch den Projektpartner Outdooractive Reserach (Outdooractive AG, 2024) ein erster Ansatz für ein Emo-Routing in der Fahrradnavigation erarbeitet. Damit soll es Radfahrenden ermöglicht werden, bei ihrer Navigation nicht nur zwischen der kürzesten oder der landschaftlich attraktivsten Routenoption wählen zu können, sondern sich auch für eine „entspannte“ und „stressarme“ Option entscheiden zu können. Eine erste Testlauf dieses Emo-Routings ist ebenfalls im Sommer 2024 geplant.

Wie wichtig ein quelloffener Ansatz auch bei Hardwarekompnenten ist, zeigt sich zum Laufzeitende des Projektes die Ankündigung von Empatica, die e4-Technologie zum August 2024 auszumustern. Ab diesem Zeitpunkt soll es nicht mehr möglich sein, auf die verschiedenen Services im e4-Kontext zuzugreifen, sprich, die API-Key Anforderung zum Aufzeichnen auf einem eigenen Gerät, das Löschen interner Daten auf dem e4 über das Portal als auch das Aufspielen von Firmware wird nicht mehr möglich sein. Aus Aspekten der Nachhaltigkeit und Wirtschaftlichkeit – hier wird sehr teurer, noch funktionstüchtiger Elektorschrott mit Einstellung eines Sevices produziert – ist dieses Vorgehen von Hardwareherstellern nicht nachzuvollziehen.

Im Kontext des Sicherheitsempfindens im Radverkehr ist es darüber hinaus ein Anliegen des ESSEM-Projekts, nicht nur die neuralgischen Punkte zu identifizieren, sondern auch der Fragestellung nachzugehen, inwiefern das subjektive Sicherheitsempfinden von Radfahrenden verbessert werden kann. Hierzu findet aktuell eine Begleitstudie des Projekts statt, die verschiedene sicherheitsrelevante Produkte im Kontext des Radfahrens gemeinsam mit Industriepartnerinnen und Industriepartnern erprobt. In einer experimentellen Produktevaluationsstudie wird im Frühjahr 2024 der Einfluss verschiedener Produkte auf das Sicherheitsempfinden der Testpersonen erforscht.

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🏆 *reviewed paper*

Employee Behaviour as a Possible Corporate System Vulnerability when Implementing Digitalisation in Smart Cities

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1 ABSTRACT

Digitizing processes to improve the citizen centered performance is one of the key challenges for Smart Cities (Radchenko, 2023) This paper contends that, whilst resolving those challenges, the implemented strategies could cause undesired outcomes. Also, this intersects significantly with urban planning considerations, as it involves the integration of digital technologies, including infrastructure, service and governance. At first glance, innovative digital technologies might render more transparent processes saving time and money for organizations. However, people, too often, disregard the threats associated with them. The latter can be classified in external and internal threats. Interestingly, companies feel threatened more by the internal ones since they cannot entirely be eliminated (Boce, 2023). In more detail, the importance of the topic emerges from the following research gap: “From the general point of view of companies, there are no real structures for security management. Also, they do not design policies that will minimize internal threats, they have not yet understood the importance and influence of man as a threatening factor…” (Boce, 2023, p.76).

The research addresses the general question of how employee behavior contributes to internal vulnerabilities affecting the security and compliance governance of digitalization implementations in a Smart City context?

The aim of this research in progress is to address this ‘human threat’ via a comprehensive systematic literature review and a consecutive empirical research design.

Keywords: employees, digitisation, smart city, planning, vulnerability

2 METHODOLOGY

A systematic literature review on web of science and scopus indexed journals will investigate the existing categories of the internal threats and of human behaviors as well as their interactions. The abstract and journal inclusion criteria refer to relevant security management and administrative structure topics. Further the implementation of digital solutions in public institutions and the impact of human factors on security, compliance and governance in this context should be apparent. To offer data-driven insights, the studies should employ empirical methodologies such as surveys, case studies or mixed-methods approaches.

Furthermore, selected sources will include only recent research within the last 10 years to ensure reference to current trends of the smart city movement. Thus, real-world examples that take a holistic view, examining besides the technology aspects also the behavioral and governance factors are reviewed. To facilitate accessibility, English and German studies will be chosen. The systematic literature review will result in more detailed research questions and in an initial conceptualization to be presented at the conference. Based on the critical realism research philosophy, the methodology to conduct empirical research pursues a triangulation approach and will be suggested at the conference.

3 QUALITY ASSESSMENT

The criteria for paper selection and/or rejection are contingent upon pertinent reliability and validity measures. It needs to be ensured that the instruments which have been used for data collection are consistent and accurately measure the variables. Potential biases in the study will be diligently examined. Ultimately, the credibility of the research hinges on the coherence between the results and the research question and / or hypotheses. Ensuring ethical standards is crucial and includes elements such as obtaining informed consent and handling sensitive data responsibly. Equally noteworthy is the open acknowledgment of potential biases and limitations in the studies, a key measure to maintain the integrity of the research. The examination aims to determine the transferability of the conclusions drawn to different corporate contexts or if they are specific to certain conditions.

4 FLOW CHART OUTLINING THE IDENTIFIED ARTICLES

The following section explains the entire inclusion and exclusion process using a flow chart model.

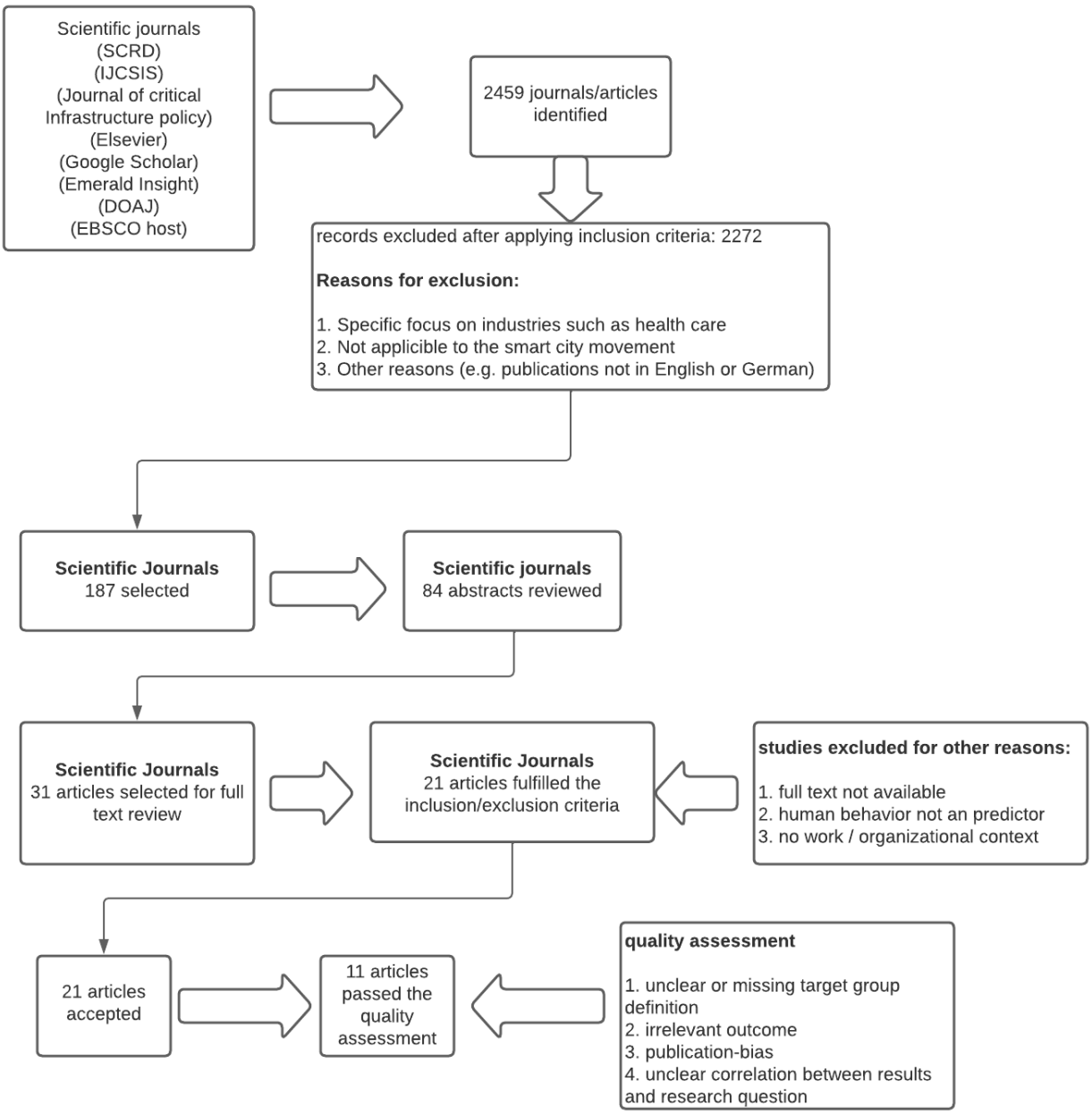

Figure 1: Flow Chart Model

5 DATA EXTRACTION FORM

The following table shows the articles that met the inclusion criteria. These were extracted on the basis of their data.

Number of study	Title	Author/s	Publication details	Year of publication	Methodology adopted	Population characteristics	Sample size	Key results
1	Analysis of the human factor as an internal threat to the security of an organization	Boce, Grigorina	Smart Cities and Regional Development Journal (V7. I2. 203) pp. 69-76	2023	Metaanalysis	employees	-	If there are not the right people to manage and use them, then the security objectives will not be achieved.
2	An information security risk-driven investment model for analysing human factors	Reza Alavi; Shareeful Islam; Haralambos Mouratidis	Information & Computer Security Vol. 24 No. 2, 2016 pp. 205-227	2016	Quantitative approach	employees	62	clear relationship between risks, incidents, and investment
3	SOFIT: Sociotechnical and Organizational Factors for Insider Threat	Greitzer, F. et al.	2018 IEEE Symposium on Security and Privacy Workshops	2018	Mixed Methods	organizations	5	Combination of behavioral and technical factors can identify threats earlier
4	Trust as a human factor in holistic cyber security risk assessment	Henshel ,D.; Cains,M. G.;Hoffman, B.;Kelley ,T.	Procedia Manufacturing 3 (2015) 1117-1124	2015	Literature analysis & Quantitative approach	User, Defender, Attacker	-	importance of trust in cybersecurity risk assessment
5	Human factor, a critical weak point in the information security of an organization's Internet of things	Hughes-Lartey, Kwesi; Li, Meng; Botchey, Francis; Qin, Zhen	Heliyon 7 (2021) e06522	2021	Quantitative approach (linear regression)	Employees familiar with IOT	1600	Framework should combine technological and social aspects
6	Moderne Arbeitswelten im Kontext fortschreitender Digitalisierung und Gefahren in der IT-Security	Kraml, Janina	Master-Thesis	2023	Qualitative approach	Manager	9	Need of security standards

7	Impact and Key Challenges of Insider Threats on Organizations and Critical Businesses	Neetesh, Saxena et.al	Electronics 2020,9,1460 (mdpi)	2020	Qualitative approach	Public and private sector organizations	105	Challenge, emanating from various employee levels
8	A Human Factor Approach to Threat Modeling	Ferro, Lauren; Marella, Andrea; Catarci, Tiziana	HCI-CPT 2021, pp.139-157	2021	Human centered approach	employees	-	gap in traditional threat modeling and system security design
9	Human Individual Difference Predictors in Cyber-Security: Exploring an Alternative Scale Method and Data Resolution to Modelling Cyber Secure Behavior	Raywood-Burke, George; Bishop, Laura; Asquith, Phoebe; Morgan, Phillip	HCI-CPT 2021, pp.226-240	2021	Quantitative approach	Humans, no specification	189	Understanding individual vulnerabilities for interventions
10	Human factors in information leakage: mitigation strategies for information sharing integrity	Wong, Wai Peng; Tan, Hwee Chin; Tan, Kim Hua; Tseng, Ming-Lang	Industrial Management & Data Systems, Vol. 119 No. 6, pp. 1242-1267.	2019	Qualitative approach	Multinational enterprises/corporations	5	addressing information leakage involves for example human governance
11	Sicherheitsherausforderungen für Smart-City-Infrastrukturen	Zimmermann, Verena et.al	Wirtschaftsinformatik & Management 2022 • 14 (2): 119–126	2022	Mixed Methods	Experts	30 (online surveys),7 interviews with 10 experts	Challenges are complex (ethical, social), technological

Figure 2: Data Extraction Form

6 SYNTHESIS

The central theme revolves around three key aspects: digitalization in smart cities, the unintended consequences of digitalization strategies, and internal threats arising from employee behavior. These outlined focal points include certain categories.

- Digitalization in smart cities:

This segment delves into the challenges faced during the implementation of digitization processes in Smart Cities.

(1) Threat Modeling and System Security Design in Smart Cities

Examining the gap in traditional threat modeling approaches and system security design within the context of smart cities, emphasizing the need for innovative strategies that consider the unique challenges presented by the integration of digital technologies and human factors in urban environments.

(2) Integrated Security Framework

Developing a holistic security framework that integrates both technological solutions and social aspects, aiming to establish comprehensive security standards and address the complexity of contemporary security challenges.

- Undesired outcomes of digitalization strategies:

Despite the potential for innovative digital technologies to enhance transparency in processes, the argument is made that implemented strategies may result in unintended consequences.

(3) Risk and investment relationship

Examining how an organization's risks, incidents, and investments in security measures are interconnected, assessing the impact of resource allocation on overall risk, and exploring strategic investments to mitigate potential threats.

- Internal threats due to employee behavior

A substantial emphasis is placed on internal threats stemming from employee behavior as opposed to external threats

(4) Human Factor and Security Management

A lack of qualified personnel can hinder security goals, and it's crucial to understand individual vulnerabilities for specific interventions, considering challenges at different employee levels and addressing multifaceted issues like ethics, social dynamics, and technology in security management.

(5) Trust and Cybersecurity Risk Assessment

Exploring the influence of trust on cybersecurity risk assessment and decision-making and integrating trust-related factors for more robust risk evaluations.

Number	Factor description	Categories				
		1	2	3	4	5
1	Examine how employee behaviours impact risk, incidents and investment.			X		
2	Examine existing frameworks integrating technological and social aspecs from an employee perspektive.		X			
3	Gauge employee trust's significance in cybersecurity risk assessment.					X
4	Identify gaps in traditional threat modeling and system security design affecting employee compliance in Smart Cities.	X				
5	Identify and address individual employee vulnerabilities.				X	
6	Evaluate challenges across employee levels				X	
7	Assess security standards' impact on employee adherence.		X			
8	Address information leakage through human governance and trust-building.					X
9	Assess organizations' security personnel adequacy.				X	

Figure 3: Interplay of factors and criteria

7 FINAL RESEARCH GAPS

The challenge with current advancements lies in the fact that information security tends to focus on the technical effects and external factors rather than on the inclusion of human factors on the internet of things context. The diverse interest groups, each with distinct expectations and requirements for IT security lack a comprehensive analysis. The interaction between individuals and their surroundings is currently unexplored. Furthermore, the various forms of internal threats are not currently correlated with the company's subsystems.

It is noteworthy that there is no complete framework of quantifiable parameters for cyber security risk assessment. Additionally, there is a lack of a procedural model that consolidates the risks associated with the insider threats.

8 INITIAL CONCEPTUALISATION

The following model is intended to illustrate the employee as an internal threat, as well as the outcome when implementing digitalization in smart cities.

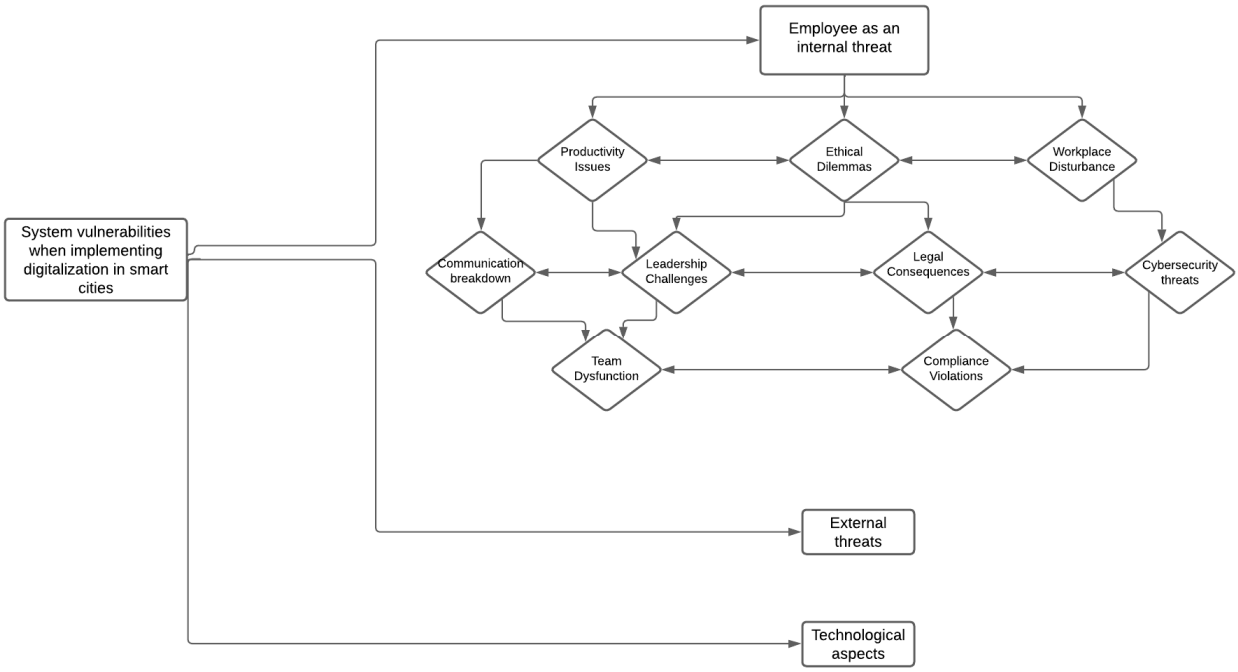

Figure 4: Illustration of the employee as an internal threat

9 RESARCH DESIGN TABLE

Table 1 is intended to show which research questions need to be explored and may have been addressed in the previously selected literature through interview questions

Research Objectives	Stage	Detailed research	Hypotheses	Interview/ Questionnaire questions	Sources
Objective 1: systematic literature review	Stage 1	Carry out a systematic literature review on employee behavior as a possible corporate system vulnerability.			see: data extraction form
Objective 2: Examine and propose effective strategies for companies to efficiently mitigate the impact of employee behavior on system deficits during the digitalization process in smart cities.	Stage 2	Carry out interviews with experts and project managers of the digitalization process in smart cities.	Implementing comprehensive employee behavior management strategies will effectively mitigate the impact of employee actions on system deficits during the digitalization process, resulting in enhanced system resilience and operational efficiency for companies.	What measures should companies take to improve their IT security in the course of digitization? How can companies ensure that their employees are informed about the risks associated with IT security and can respond accordingly? What role do IT security training and education play in enhancing IT security in companies?	Ferro, L., Marella, A. and Catarci, T. (2021) 'A Human Factor Approach to Threat Modeling Kraml, J. (2023) 'Moderne Arbeitswelten im Kontext fortschreitender Digitalisierung und Gefahren in der IT-Security'.
Objective 3: Investigate the specific behavioral factors that contribute to vulnerabilities in corporate systems during the digitalization process within smart cities.	Stage 2	Carry out interviews with experts and project managers of the digitalization process in smart cities.	Specific behavioral factors, such as lack of employee cybersecurity awareness, resistance to change, and inadequate training on digitalization processes, contribute significantly to vulnerabilities in corporate systems during digitalization in smart cities.	Does your company educate you about risky behaviors that could unintentionally leak data and information? In spite of such education, employees continue to show risky behaviors and put data at risks. Why is this so? What could change these risk behaviors? Do you and your friends or colleagues talk about work	Raywood-Burke, G. et al. (2021) 'Human Individual Difference Predictors in Cyber-Security: Exploring an Alternative Scale Method and Data Resolution to Modelling Cyber Secure Behavior' Wong, W.-P. et al. (2019) 'Human factors in information leakage: mitigation strategies for information sharing integrity

				(suppliers, contractors, and customers) during tea time and lunch hour?	
Objective 4: Examine how the above risks/ factors influence other smart cities and what known strategies they use to minimize the risk of danger from employees	Stage 3	Sending and evaluating questionnaires to smart cities	To be continued	To be continued	Kraml, J. (2023) 'Moderne Arbeitswelten im Kontext fortschreitender Digitalisierung und Gefahren in der IT-Security'. Saxena, N. et al. (2020) 'Impact and Key Challenges of Insider Threats on Organizations and Critical Businesses Wong, W.-P. et al. (2019) 'Human factors in information leakage: mitigation strategies for information sharing integrity
Objective 5: To carry out an initial conceptualization	Stage 4	Comparison of the findings from the literature review, the interviews and the questionnaire			

Table 1: Research Design Table

10 OUTLINE OF RESEARCH METHODOLOGY

Later research is suggested. The methodology is briefly outlined in the following.

A non-probability sample, based on certain criteria, should be conducted in the form of a targeted selection of employees across diverse hierarchical levels within public administration organizations.

A mixed methods approach should be used as a research method. Therefore, a qualitative approach to gain in-depth knowledge about employee behaviors and motivations is recommended. An exploratory approach could be chosen to generate new insights and to understand specific aspects of behavior. Moreover, expert interviews can validate the findings obtained through observation.

For the quantitative aspect, company data offering insights into the weakest subsystems should be analyzed. Additionally, a survey may be administered to the entire workforce to capture attitudes towards employee behavior and organizational culture. This could be descriptively evaluated in the form of a cross tabulation, frequency analysis, significance, and correlation. Additionally, referring to explanatory cause-effect analysis could be conducted via factor analysis and multiple regression analysis.

11 CONCLUSION

The systematic literature review shows that companies actually tend to focus on the technological aspects and external threats rather than on the much closer danger, their own employees. Although the various internal threat types have been analyzed in the literature, this must always be viewed in the context of stakeholder interests and corporate culture. There is also a need for research into the interaction of employees with their environment, as well as the creation of a framework that includes quantifiable parameters for cyber security risk assessment. the interplay between risks and insider threats also needs to be examined more closely.

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🏆 *reviewed paper*

Empowering Ageing: Navigating the Future of Digital Healthcare for Older Adults – a Rapid Review of Perspectives and Challenges

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1 ABSTRACT

Digital health offers innovative and promising solutions addressing the challenges of an ageing population. The pandemic has shown the advantages of treating and monitoring patients with assisted technology and their cost-effectiveness. Several studies demonstrate that older people can benefit from assisted technology to monitor their health, manage their medication and treatment, and receive online consultations by healthcare providers. Nevertheless, a growing literature show conflicting results with respect to the integration of digital devices for older people in practice. Integration of digital health means to explore how different processes are employed, incorporated and connected with each other in order to realise a positive outcome for older people. Recent studies demonstrate that older people use the internet in diverse ways and a gender gap has been noticed in the way older men and older women make use of modern technology in everyday life. Moreover, some studies suggest that Ageism would pose a risk of excluding older people to use digital health. However, some focus on older people's experiences and perceptions which determine the use of digital technology and the meaning for them. Hence, there is a sparse understanding of how digital health is implemented and experienced by older people in practice. Therefore, this paper provides a rapid review of the gaps of knowledge and understanding in how digital health is implemented, perceived, and experienced by older people.

The objectives are: 1. To examine the practical applications and effectiveness of assisted technology in the care of older adults, specifically focusing on health outcomes. 2. To descriptively map the key themes and trends in assisted technology for older adults, aiding in the formulation of targeted future research priorities. By addressing these objectives, this paper aspires to contribute to the advancement of digital health for older adults, offering insights that can inform policy, practice, and future research endeavours.

Keywords: planning, smart homes, digital health, ageing, elderly

2 INTRODUCTION

It is estimated that the global population of people aged 60 years and over will increase to 1.4 billion by 2030 and 2.1 billion by 2050 (WHO, 2024). This means that the way healthcare is structured needs to adapt to the complex health needs of this distinct population. Since the pandemic, digital technology has come to the forefront and is increasingly being integrated into healthcare, with huge potential to access health services remotely at any place and time. This was particularly pertinent during the height of the COVID pandemic. Without this opportunity, many vulnerable people of all ages would have had a disadvantage with respect to their experiences of health during periods of lockdown. The incorporation of digital healthcare in the medical field raises significant issues concerning access, technical literacy, and the possibility of worsening inequality among older adults. This necessitates a review of healthcare systems to ensure that they prioritize the unique preferences, requirements, and values in this age group while remaining person-centred. Therefore, the focus of our paper is on older people, examining the implications of digital healthcare and exploring how it is experienced, implemented and perceived by them to discover insights that can inform the creation of more inclusive, accessible, and effective digital healthcare solutions that meet the specific needs of older adults.

Digital health confronts us with two major concepts: namely 'health' and 'digital'. So, the question arises what brings these two seemingly contradicting terms together? In essence, 'digital' refers to data or signals being recorded, stored, expressed, and transmitted as series of digits, 1 and 0 (Odone et al. 2019). It serves as the foundation for technical processes of how information is processed and delivered as well as how

transitional changes are recorded and managed (Iyamu et al. 2021). Throughout the evolution of the internet, digitization has been integrated into health to improve health outcomes Rowlands (2020). Since the development of the first computers, there have been significant strides in health informatics. Once hardware and software were introduced in the 1960s, data-processing applications were applied in hospitals (Rowlands 2020) to support healthcare processes. With the maturity of the internet and the development of Artificial Intelligence (AI), a breakthrough occurred with developing health apps and wearable devices (Rowlands 2020). This all has significantly led to a new approach of health management and delivery away from traditional concepts.

The conceptual understanding of "health" has been elaborated upon many times and modern concepts of health agree that this is dynamic and relative (Svalastog et al. 2017). To make social health care services operational the World Health Organization (WHO) defined health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" in 1948. Since then, this definition has been debated by many scholars regarding the wider and multi-sided understanding of this concept. Van Druten et al. (2022) analysed the literature of this concept and concluded that 'health' can be viewed from a subjective, professional, and philosophical perspective. This implies different meanings in different settings. Therefore, Krahn et al. (2021) define it as follows: "health is the dynamic balance of physical, mental, social, and existential well-being in adapting to conditions of life and the environment". This reconsideration of the concept has led to a broader understanding that includes the following dimensions: a) health is dynamic and varies along a continuum, b) it is multi-dimensional, c) health is distinct from function, d) balance is achieved through adaptation, and e) health is influenced by social and environmental influences (Krahn et al. 2021).

There is still a lack of common understanding what "digital health" means (Fatehi et al. 2020; Rowlands, 2020; Wienert et al. 2022). Nonetheless, we will endeavour to explore the commonalities of different definitions and concepts under this umbrella term and help in bridging the gap between technology and health. The WHO (2024) provides a broad definition of digital health as "the field of knowledge and practice associated with the development and use of digital technologies to improve health." It is an expansion of the concept of eHealth and many other terms appear to be used inter-changeably such as mHealth, telehealth, telemedicine, and assisted technology. The main idea behind this concept is to enhance the delivery, efficiency, and processes of healthcare delivery. One of the major challenges is determining how this concept can be integrated into existing health concepts such as public health (Wienert et al. 2022). An exploration of the literature suggests that the focus of digital health is on the management of health and illness rather than the proper use of technology itself (Fatehi et al. 2020; Ronquillo et al. 2023). By 'proper use,' we mean that assisted technology should not be viewed solely as a mandatory tool but as a meaningful aid to achieve certain well-being and overall health goals for individuals. This also means that digital health is a tool that allows care coordination processes in an efficient manner and provides patients with more control and autonomy over their health management rather than being controlled by the digital health (Rowlands 2020).

Most definitions of digital health agree that it is about the integration of digital technologies to achieve public health goals and improve health outcomes in an efficient manner (Iyamu et al. 2021). The features of digital technologies such as "personalisation and precision" (enhancing the training of professionals and patients through AI), "automation" (make a process work automatically), "prediction" (using electronic data to inform AI and non-AI prediction models), "data analytics" (facilitating the sharing of large amounts of data), and "interaction" (monitoring and interpreting health through communication) can be summarized as a conceptual framework of digital technologies (Odone et al. 2019). Three main perspectives have been suggested by Iyamu et al. (2021) to encapsulate the complexity and comprehensiveness of digital technologies in health care practices as 1) "Digitization" (the technical process of converting existing analogue records to digital data), 2) "Digitalisation" (reflecting the cultural shifts necessary to incorporate and sustain technologies in healthcare delivery) and 3) "Digital transformation" (encompassing fundamental changes to the culture, operational models and goals of public health services). It means that technologies not only assist and support processes in healthcare services but also transform the quality and management of healthcare. Most definitions agree that there is a fundamental shift in the way healthcare is going to be delivered by placing the patient at the centre. This grants patients the ability to take control over their health and health behaviour, enabling them to be more autonomous than ever before.

This paradigm shift towards preventive, proactive health and data-driven decision making involves benefits and challenges (Bangare et al. 2023). Patients have the chance to oversee their own health and health behaviour change is increasingly centred in the hands of patients. However, this does not come without important challenges that need to be considered for a successful practice implementation. Data protection and privacy are one of the factors that need attention to protect personal patient information and to ensure the secure sharing of this data electronically with other professionals or agencies. In addition, several studies have shown that there are gender gaps and a digital divide in internet usage among younger and older people (Bangare et al. 2023; Fadzil et al. 2023; Lu et al. 2022; Shi et al. 2023; Wang et al. 2023). To combat health inequalities, there is a need to adopt a multidisciplinary approach that considers psychosocial and economic differences among populations to streamline healthcare. Older people face unique challenges due to age-related changes of varying degrees alongside possessing diverse levels of digital literacy. However, there is significant potential for older people to be digitally inclusive when guided with the right information and interventions (The Lancet Digital Health, 2023).

Therefore, the aim of this paper is to explore how digital health is experienced, perceived, and adopted by older people through undertaking a rapid review of the literature. This has the potential to inform future research and healthcare programmes, aiming to improve health outcomes and the patient experience for older adults. A rapid review is useful when there are time constraints and policy-makers or professionals have to make immediate decisions (Moons et al. 2021). Whilst systematic reviews are more detailed and focus on using statistical techniques to synthesize the data from several studies and hence, they are more time-consuming (generally between 6 months and 2 years) , rapid reviews tend to be more time-efficient (Hamel et al. 2021). Because rapid reviews are not as detailed as systematic review, there is a risk of bias. Therefore, the Cochrane Collaboration has established the Cochrane Rapid Reviews Methods Group to outline the standards (Garritty et al.2021). Our approach was to use this as a guideline for formulating the research question, limiting our searches, and analyzing the sources found into a comprehensive yet timely manner. The intention is merely being descriptive, so future research programs can be developed to inform healthcare practices.

2.1 Search strategies

The literature search was undertaken by using the following databases Google Scholar, Medline, Medline Plus PubMed, and EBSCO. The first step involved to create a list of Mesh terms which is shown Table 1 below.

Search terms and combinations
(Digi* AND acc*) AND old* people* , (Home* AND care*) AND (digi* health*)
(Digi* AND tech*) AND (old* AND people*)
Experience* AND (digi* AND care*)
(digi* AND health* AND tech*) AND (care* AND old* AND adult*) AND COVID-19*
(Internet* AND tech*) AND (old* AND people*) OR (eld*)
(digi* AND engage*) AND (old* AND age*)
(Digi* AND health* AND/OR care*) AND adopt* AND old* people*
(Digi* AND health* AND/OR care*) AND intervent* AND old* people*
Tech* AND (support* AND old* people*)
(Digi* AND health* AND/OR care*) AND adopt* AND old* people*
virtual* AND Real* AND old* People* OR adult*
health* AND inform* AND old* People* OR adult*
(Digi* AND health* AND/OR care*) AND (care* AND transition*)

Table 1: Mesh Terms and combinations of terms

Two authors (ASM and GC) undertook the searches using these Mesh terms above independently. The papers were included on an Excel spreadsheet which was shared as a document amongst all the authors. The first stage involved screening the titles and abstracts concerning digital health and older people. The second stage involved screening the collection of papers against our inclusion and exclusion criteria. The third stage involved a thorough reading of each included paper by four authors (ASM, GC, AT, SS) independently and making an assessment on the quality on the papers using the CAT (Critical Appraisal Tool) by Joanna Briggs Institute (2017). The process of screening is shown in the PRISMA flow Diagram 1 below. We included n=59 for our descriptive analysis and used a thematic analysis approach according to Braun and Clarke (2006).

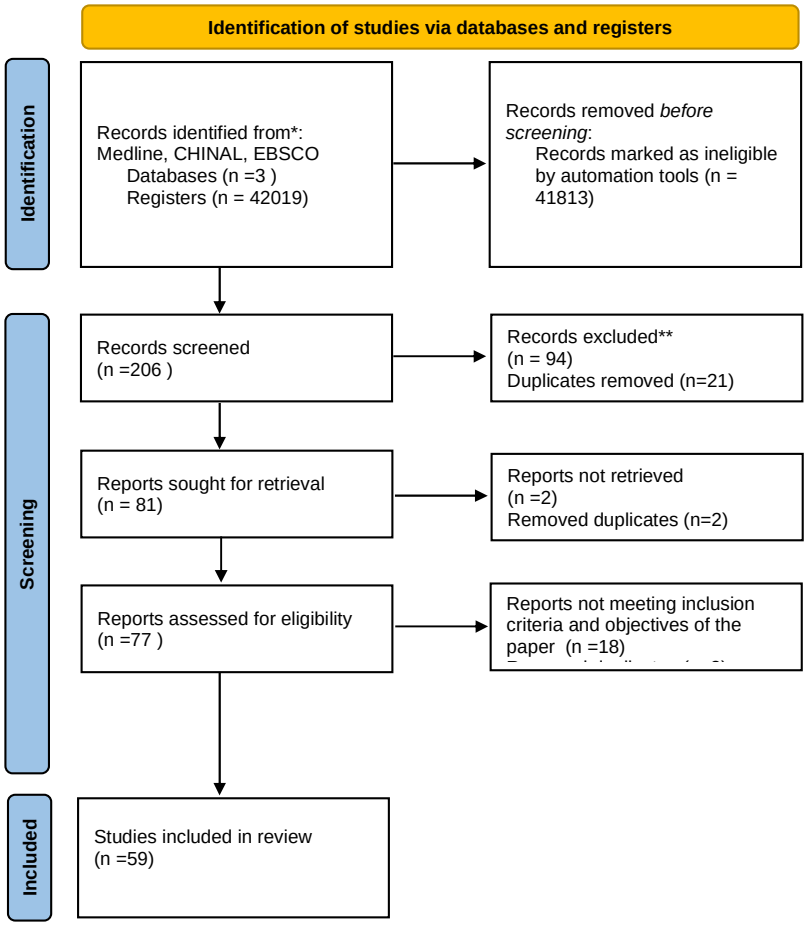

Diagram 1: PRISMA Flow diagram

2.2 Inclusion Criteria

Studies published after 2019 were included, thus setting a marker for the beginning of the pandemic and with this the acceleration of digital healthcare technology. As many studies define older people at the age of 60 and above, we used this as a cut-off age. We also considered cross-sectional studies focussing on older adults 60 and above as well as younger than 60 comparing older and younger age groups. Specifically, illnesses and disabilities related to older age groups such as dementia, frailty, cognitive impairment, and geriatric care were included. There were no restrictions as such to certain illnesses and chronic conditions. Systematic reviews, meta-analysis, scoping reviews, or umbrella reviews were also considered. Studies were also considered that focus on the evaluation or intervention of digital health devices by older people. We considered quantitative, qualitative and mixed methods studies, randomized controlled trials (RCTs), observational studies, and empirical research related to training on digital healthcare for older people. As some studies were conducted in Asia, Australia and the United States, this helped us to broaden the scope and fine-tune our understanding of how older people are ageing with health technologies and the factors influencing their behaviour and digital usage within this context. Papers written in English and German languages were considered. In addition, we also considered conference papers and abstracts and dissertations focussing on digital healthcare for older people.

2.3 Exclusion Criteria

We excluded papers published before 2019 that focused on adults younger than 60 years of age. Studies that only looked at medical records, diagnostics, and prescriptions, or social inclusion without any focus on health were also excluded. Additionally, we did not consider papers that focused on social inclusion, caregivers' or practitioners' experiences, or the general population. Empirical research that focused on general internet use unrelated to health was also not considered. Furthermore, we did not include e-health apps or databases used by healthcare professionals to diagnose illnesses as they did not align with our research objectives for this review.

3 FINDINGS

The final analysis included n=59 papers for this review of which 20 were review papers, 11 were concerned with interventions, 2 were randomised controlled trials, 18 were qualitative studies, 2 were quantitative studies, 3 were cohort studies and 3 mixed methods studies. A narrative synthesis was performed to present the findings according to Popay et al. (2006). This approach of presentation is useful when you have diverse sources of information and comparing different factors. Hence, we have summarised the findings into two themes: Assisted technology in diverse contexts, Dimensions of assisted technology implementation.

3.1 Assisted technology in diverse contexts

The use of assisted technology was studied in the selected papers with different intentions, focussing on barriers and facilitators, and by including a diverse sample size. In the following two sections, this will be elaborated in more detail.

3.1.1 The context and intention of study

In our review the research-evidence of the presented papers provided a diverse and rather 'patchy' picture in which context assisted technology was used and implemented. These contexts pertained to the use of wearable devices (Moore et al. 2021; Peng et al. 2021; Wu et al. 2023), telehealth (Ding et al. 2023; Hullick et al. 2022; Jiang et al. 2022; Raja et al. 2021 Sari et al. 2023), few studies focussed on smart home technology for older people (Aggar et al. 2023; Facchinetti et al. 2023; Oyiobi et al. 2023). Three studies used a pre-and post-intervention study design (Aggar et al. 2023; Sari et al. 2023; Tuena et al. 2023). Many studies focussed on the physical outcomes of older people such as examining how mobility and functionality improved over time by implementing assisted technology (Dermody et al. 2020; Oyibo et al. 2023; Pais et al. 2020; Ren et al. 2023; Sari et al. 2023) and rehabilitation and risk of falls (Gasper & Lapao, 2022; Tuena et al. 2023; Zak et al. 2023). Few studies also focussed on whether assisted technology was feasible in a particular context such as a tele-home-based exercise program by Sari et al. (2023) or an eHealth home-based intervention to improve dietary and physical activity (Gomes et al. 2021). Some studies showed lack of detail in reporting their findings and came to conclusions that assisted technology was helpful based on small sample sizes (Chang et al. 2021; Guo et al. 2022; Hullick et al. 2022;Kim et al. 2023). A few studies focussed on behaviour change such as diabetes management (Balsa et al. 2020; Ren et al. 2023).

3.1.2 Barriers and facilitators

Since many of our papers were systematic reviews followed by scoping reviews, the quality of their reporting varied significantly. Many focussed on how assisted technology impacted physical health and quality of life (Oyibo et al. 2023; van Acker et al. 2023; Wu et al. 2023; Zak et al. 2022; Zasvlasky et al. 2019). Some specifically focussed on barriers and facilitators whilst using assisted technology for older people (Kebede et al. 2022). Although the reporting varied in these reviews, they still reported similar trends pertaining to the fact that assisted technology was helpful and improving physical health and overall functioning. User engagement was reported in some studies and revealed that older people are interested and accepted to use assisted technology (Aslan et al. 2024; Gomes et al. 2021; Steng et al. 2022; Wanyonyi et al. 2022) , but they still experience barriers that hinder them to feel confident and they feel uncertain (Wilson et al. 2021; Zoorob et al. 2022). When interpreting these findings, one must consider that some studies have used samples from larger population studies (Brunzini et al., 2023; Kouri et al. 2023; Linn et al. 2021) which questions a bias towards the cohort group chosen.

3.1.3 Profile of older people

Participants across the studies ranged in age from 51 to 94 years, with a significant focus on older adults, specifically those aged 60 and over. One study using a cross sectional design recruited participants from age 18 up to 64. This includes a diverse age representation within the older adult population, from early retirement to advanced age, highlighting a broad interest in ageing populations across different health contexts.There is a mixed gender representation, with a noticeable proportion of studies including more females, especially in studies with older adults. However, specific studies also highlight a balanced or male-dominant participation. The sample sizes of the studies varied significantly, with some as small as 7 participants and others as large as 6183 participants. This demonstrates a broad spectrum of study scales ranging from individual case studies to large-scale surveys and interventions.

The participants come from varied health backgrounds, including dementia-free community dwellers, individuals with mobility and vision problems, people living with dementia undergoing telehealth exercise programs, and participants with conditions like asthma or COPD using digital mHealth devices. Many studies focus on older adults without specific health conditions but aim to understand the impact of interventions on general health, mobility, or disease prevention. A notable number of older adults live alone, focusing on individuals who may require additional support or interventions tailored to solitary living conditions.

Various studies have been conducted between 1998 and 2024 in different parts of the world, such as Asia, Europe, the Middle East, and mainly developed countries. This indicates a broad geographical distribution, with more emphasis on affluent regions. Few studies involved low-income participants, highlighting the need for interventions catering to people from different socioeconomic backgrounds.

3.2 Dimensions of assisted technology implementation

3.2.1 The practical dimension

In many qualitative studies undertaken older people reported positive as well as negative benefits using assisted technology (Ferreira-Brito et al. 2024). Intrinsic and extrinsic barriers were identified by some studies (Jakobsson et al. 2019; Korkmaz et al. 2022; Moore et al. 2020; Raja et al. 2022; Tu et al. 2021; van Acker et al. 2023;Wilson et al. 2022;). Facilitators mostly pertained to the engagement and availability of a healthcare professional and ability to live independently. At the same time, this can be equally a barrier, if a professional is not available to help and this in turn could hinder older people to use digital technology. This has not been specified in the studies we examined though. However, barriers that caused anxiety and being wary of assisted technology were related to physical capability of using it, the convenience of logging in and reading icons, safety concerns were reported in most studies and data protection (Aslan et al. 2023). One study clearly stated that older people felt that the human contact could not be replaced (Raja et al. 2021). Hence, assisted technology for older people is a supportive mechanism to their health maintenance rather than a complete tool to manage their health.

3.2.2 E-health literacy variation within this population

There is indication in some studies that older people require time to feel confident with assisted technology and build up their efficacy which is often positively reinforced by professionals' support to train them or their family (Cao et al 2023; Kebede et al. 2022; Tu et al. 2021). Often there is missing information on how much digital experience and skills those older people had who participated in the studies we selected. Whilst some older people may have had prior experience with digital technology during their working years (when they were mostly younger), the oldest members of this population may have had little or no exposure to technology. This presents a challenge when it comes to developing assisted technology that can cater to the entire cohort of older individuals.

3.2.3 Emotional experience

Using digital health for older people entailed many aspects to their emotional journey. We identified n=18 qualitative studies focussing on the experiences and perceptions of older people in relation to using digital health. Motivation, confidence to use it, feeling connected to their healthcare provider, and understanding the purpose of why digital technology might be helpful in their situation were critical during the implementation of digital health technology (Acker et al. 2023; Aslan et al. 2024; Fothergill et al. 2023; Lindberg et al. 2021). For many study participants the following factors played a critical role whilst using digital health care pertaining to their relationships, efficacy, motivation, safety and autonomy (Aslan et al. 2024; Fothergill et al. 2023; Moore et al. 2020; Raja et al. 2021).

4 DISCUSSION

This paper intends to provide a rapid review of the gaps in knowledge and understanding in how digital health is implemented, perceived, and experienced by older people. For this we developed the following two objectives: 1. To examine the practical applications and effectiveness of assisted technology in the care of older adults, specifically focusing on health outcomes. 2. To descriptively map the key themes and trends in assisted technology for older adults, aiding in the formulation of targeted future research priorities. Overall,

one can say that primary research studies and review studies vary in their aims and overall objectives indicating that older people are a complex population and chronological age may not be sufficient enough when exploring how assisted technology should be implemented. Nonetheless, most studies agree that older people face extrinsic and intrinsic barrier that determine their experience using digital health technology.

The review emphasizes the importance of older adults' health and their overall well-being, with a particular focus on the integration of digital health technologies. The study participants belong to diverse age groups, have varying health conditions, and live in different situations, reflecting the complexity of ageing and highlighting the need for individualized and accessible health interventions. Although the studies' geographical distribution is diverse, most are concentrated in developed countries, indicating a potential gap in research from less developed regions or diverse cultural contexts. Our review confirms Berridge et al.'s (2019) study that multicultural contexts and individual profile should be considered. The various interventions and methodologies used in these studies demonstrate the dynamic and multifaceted nature of digital health and ageing research, highlighting the challenges and opportunities in improving health outcomes and quality of life for older adults.

Numerous studies have found that women are more prevalent in participant samples due to their longer life expectancy. Therefore, digital health research requires a gender-sensitive analysis and it is essential to understand that older women's engagement with technology is influenced by various factors such as life experiences, societal roles, and individual capabilities. The Cumulative Advantage/Disadvantage theory (Merton 1968) suggests that differences in technology use and confidence among older women may be rooted in lifelong social and economic factors. Historically, women are more likely to assume homemaker roles, resulting in fewer opportunities to interact with technology in professional settings, potentially leading to lower efficacy in using digital tools in later life.

This perspective emphasizes the need for digital health initiatives to consider gender dynamics and how historical and societal contexts influence technology use among older adults. Tailoring digital health interventions to address these unique challenges and leveraging theories of lifespan development can enhance the effectiveness and accessibility of technology for older women, ensuring that digital health solutions are inclusive and supportive of all users' needs. We have encountered no study focussing on specifically older people with migrant backgrounds as this could have played crucial role in the level of ehealth literacy, language and cultural factors impacting it. Our review confirms that digital health cannot fit everyone and needs to be tailored according to the individual needs of older people (Berridge et al. 2019; Peng et al. 2021) and that chronological age as an inclusion criterion alone may not be suitable for research design. Hence, we propose incorporating different criteria for recruitment when designing a study that could be based on common comorbidities or health conditions rather than age.

5 CONCLUSION

As we explore the ever-changing landscape of digital health, it is important to realize that a one-size-fits-all approach is no longer practical, especially regarding the unique needs of older adults. Integrating digital technologies into healthcare has opened new opportunities to improve quality of life and health outcomes. However, we still have a long way to go to achieve genuinely inclusive digital health. The diversity among older adults, not just in age but also in gender, lifestyle, cultural background, and health status, highlights the need for more personalized, adaptable, and culturally sensitive health solutions.

This requires a significant rethink of digital health interventions. Future research should not only focus on understanding the unique experiences of underrepresented groups, such as older women and migrants but also on developing technologies that are as dynamic and varied as the populations they aim to serve. By embracing this diversity, we can unlock the full potential of digital health to empower every older adult, making technology an aid and a cornerstone of healthy ageing. As we move forward, we should be guided by older adults' diverse voices and experiences, ensuring that the digital health revolution is inclusive and equitable. The age of personalized digital health is here, and it promises a brighter, healthier future for all.

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Evaluating the Impact of Urbanisation on Climate Change: A Case of Kochi City, Kerala State, India

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1 ABSTRACT

Urbanization significantly impacts climate by intensifying the urban heat island (UHI) effect, leading to increased heat-related risks from climate change. Changes in land use and land cover (LULC) during urbanization processes exacerbate heat stress in growing cities. The urban surface composition, structure, and emissions from various activities contribute to local climate changes that can be more pronounced than global climate predictions. With over half of the world's population residing in cities, which are often densely populated, the current urban population of 55% is projected to reach 68% by 2050. Cities typically have temperatures that are 2-3 °C warmer than their surroundings, with nighttime and wintertime variations being the biggest. Urban climate impacts like these make inhabitants more susceptible to upcoming environmental shifts, which makes cities ideal locations for climate adaptation and mitigation. The urban heat island effect, which occurs when cities are much warmer than surrounding rural regions, can amplify the effects of heat waves and increase urban energy demand for cooling. Keeping the aforesaid knowledge in mind, Kochi, a coastal city in Kerala State has been chosen as the study region for further detailed investigation. The study aims to evaluate the urban growth in the city over two decades from 2001 to 2021 and has an impact on the effect of urban heat islands through spatiotemporal analysis. The thermal load and dynamic potential layers are evaluated and integrated to generate a Climate Analysis Map to explore the hotspots of the study region. Based on the findings, the study concludes with plausible guidelines and strategies to minimize the impact UHI effect and to promote a sustainable built environment.

Keywords: climate change, complexity, urban heat island, land surface temperature, urbanisation

2 INTRODUCTION

Over half the world lives in cities and 70% of the population will live in cities by 2050. Over 60% of the land expected to become urban by 2030 is undeveloped. Asia's urbanisation rate will reach 50% by 2020. Only New York and Tokyo were megacities in 1970 but now Asia has 13 megacities, Latin America four and in 2025, 11.6% of urban dwellers will be in megacities, up from 9.9% in 2011. More than half of urban residents will live in small cities with less than 500,000 population. Africa and Asia will urbanize rapidly in the coming decades with Africa's urban population becoming three times and Asia's will 1.7 times in the next four decades. Cities emit up to 70% of greenhouse gases. Urban economic activity accounts for 55% of GNP in low-income nations, 73% in middle-income countries, and 85% in high-income ones. Urban heat islands (UHIs) are a significant concern in rapidly urbanizing areas like Kochi city in Kerala, India. The UHI effect, where urban areas experience higher temperatures than their rural surroundings, is exacerbated by factors such as population density, land management practices, and impervious surfaces (Elsayed (2012) Singh & Grover, 2014). Studies have shown that UHIs can lead to adverse effects such as increased thermal stress on citizens, elevated levels of air pollutants, and compromised human health and comfort (Graça et al., 2021; Liu et al., 2021). The phenomenon of UHIs is particularly important in cities and can create a vicious cycle where energy-intensive cooling methods contribute to further temperature increases (Dorghamy, 2022). Remote sensing technologies, such as Landsat data analysis, have been utilized to study UHIs and assess their impact on urban areas (Abraham et al., 2023; Ehsan et al., 2017). These technologies provide valuable insights into the spatial correlations between land use, surface temperature, and vegetation indices, aiding in understanding the dynamics of UHIs (Ehsan et al., 2017). Additionally, studies have highlighted the role of green spaces in mitigating UHIs by reducing solar radiation input and lowering temperatures through shade and transpiration (Radhakrishnan & Geetha, 2021; Qu et al., 2023).

3 STUDY REGION

Kochi, located in Ernakulam district of Kerala in India, is occasionally used to refer to a group of islands and towns that includes Ernakulam, Mattancheri, Fort Cochin, Willingdon Island, Vypin Island, and Gundu Island. Thrikkakara, Eloor, Kalamassery, and Trippunithura are part of the urban agglomeration. Kochi is a rapidly growing metropolitan centre on India's southwest coast, between 090 45' N and 100 20' N latitude and 760 10' E and 760 35' E longitude, with a shoreline spanning up to 47 kilometres. Estuaries are present which are nourished by perennial rivers that weave their way across the metropolis. Most of Kochi is below sea level. The climate in Kochi is tropical monsoon and due to its proximity to the equator and seaside position, it has low seasonal temperature change and moderate to high amounts of humidity. Temperatures in the air range from 20 to 35 °C (68 to 95 degrees Fahrenheit). Kochi Corporation covers an area of roughly 94.88 square kilometres. In terms of geographical size, Kochi Corporation is one of the smaller municipal corporations in the country, but it is heavily inhabited and highly urbanized. The Corporation has 74 wards, and the city's population is expected to reach over 6.5 lakhs by 2021.

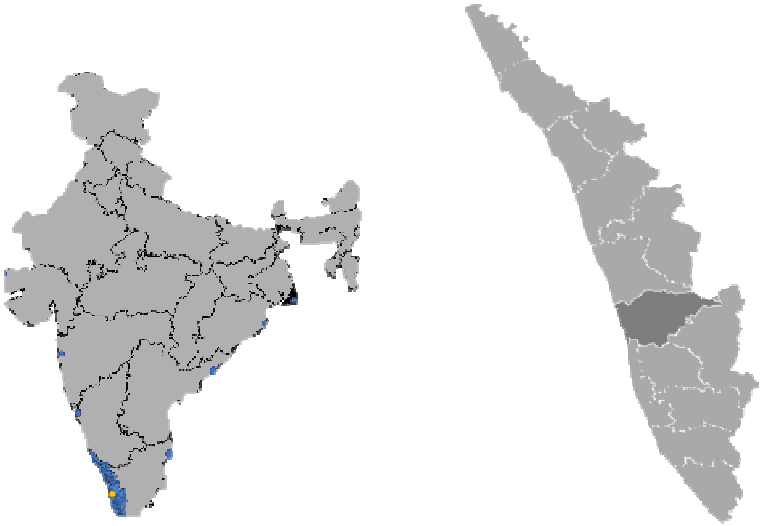

Figure 1 (left): Study Area India. Figure 2 (right): Study Area; Kerala. Source: authors.

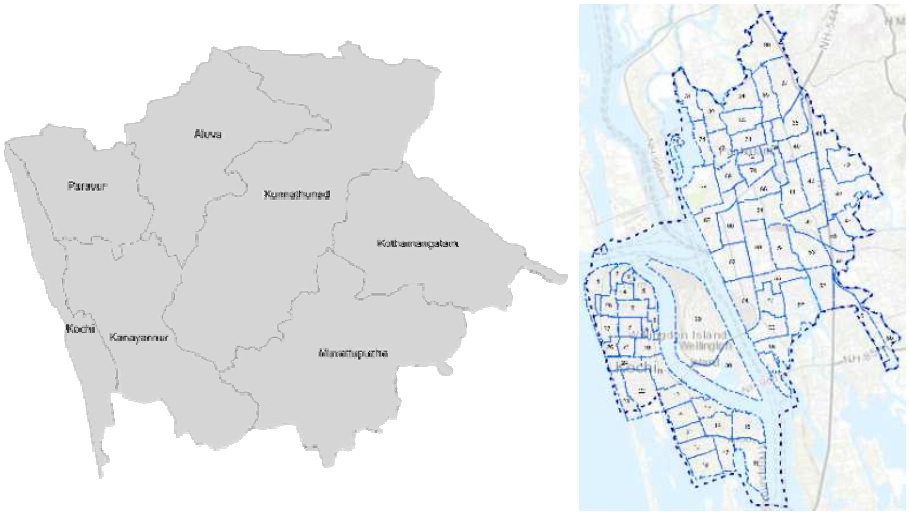

Figure 3 (left): Study Area Ernakulam District. Figure 4 (right): Study Area Kochi Municipal Corporation. Source: authors.

4 LITERATURE REVIEW

Urbanization is the process through which people migrate from rural to urban regions, resulting in the emergence of larger, more complex cities. Cities are more complicated because they contain a wide range of activities, including economic, social, and environmental issues. The different factors that drive the growth of cities are referred to as urban dynamics. Demographics and economic, social, political, and environmental issues are examples of these factors that drive the city's growth. The influence of these processes is determined by the city's unique circumstances. Because of the numerous elements at play, such as population

increase, land use, transportation, and infrastructure, urban dynamics are intricate. All of this may put a strain on the environment and the quality of life for individuals who live in cities. Urban planning is essential for dealing with the complexities of urban growth. It entails comprehending how various elements interact and forecasting how their activities will affect the city. This can aid in identifying areas of possible conflict or opportunity and in making decisions that will help the city flourish sustainably. Because urban expansion is difficult, cities require careful planning to ensure that everyone benefits.

Climate change is already affecting urban life, from overheating and floods to migration and economic turmoil. Urban leaders, governments, and multilateral organizations must work together to build climate resilience at scale, helping mature and emerging cities address rapid urbanisation, water resilience, congestion, air quality, green space per capita, land degradation, and urban sprawl. We assess and analyze climatic dangers and nature's influence in every urban system, from transit to buildings to social fabric, to help people prepare for these challenges. Kochi has a tropical monsoon climate, with heavy rainfall from June to September. Urban growth must include climate conditions to be sustainable and environmentally friendly. The city floods during the monsoon season due to its low-lying geography and high rainfall. Climate-responsive design should prioritize stormwater drainage systems, flood-resistant infrastructure, and land-use planning that avoids flood-prone areas. Green spaces in cities help reduce the urban heat island effect, which causes cities to be warmer than rural areas due to the high concentration of heat-absorbing materials like concrete and asphalt. Climate-responsive development must emphasize parks, gardens, and green roofs to cool the city. Energy-efficient buildings reduce the city's carbon footprint. Climate-responsible building design prioritizes energy-efficient structures that use renewable energy sources like solar and wind and should prioritize every vulnerability for conditions of living.

4.1 Vulnerability assessment

4.1.1 Urban Sprawl

Urbanisation extends metropolitan regions by creating homes and commercial centres farther from urban centres and connecting them with new main roadways. Suburban sprawl, or urban sprawl, is the extension of a city and its suburbs to low-density, auto-dependent development over rural terrain. As the city's population has risen, housing and infrastructure needs have skyrocketed, leading to chaotic and uncontrolled urban expansion. Traffic, infrastructural, and environmental issues resulted. Kochi's urbanisation has destroyed agricultural land, natural habitats, and increased pollution and affected water quality. Kochi's urban boom has caused rural migration, livelihood loss, and increased social and economic inequality.

4.1.2 Land Surface Temperature

Urbanisation changes urban land cover, usually through the reduction of vegetation, which affects surface climate. Due to heat capacity differences, materials with the same solar radiation have different temperatures. Urban climate depends on land surface temperature. Urbanisation can disrupt many natural processes, so studying its effects on Land Surface Temperature (LST) is crucial. Urbanisation and land usage have modified Kochi's land surface temperature (LST). Urbanisation and land usage have modified Kochi's land surface temperature (LST). When built up, vegetation-covered areas may have higher temperatures. Heat-related diseases including heat stroke and dehydration can increase with urban land surface temperature. Kochi, with a year-round tropical climate with high temperatures, is especially at risk.

4.1.3 Urban Climatic Map

Urban heat islands, air pollution, and floods can be identified using urban climate maps. Urban climate maps show urban heat islands as hotter areas of the metropolis. These areas often have few trees, plenty of concrete and asphalt, and a high building density. Increased green space, green roofs, and surface reflectivity can reduce urban heat islands. Urban climate maps can also show air pollution levels. Industrial activity, traffic, and green places may affect air pollution.

4.1.4 Urban Heat Island

Cities are usually warmer than rural areas. The city's size and shape affect the urban heat island's severity. Changes in ground cover, buildings' bulk and canyon-like shape, and vegetation decline cause heat absorption. Heating and other energy uses raise city temperatures, especially at high latitudes in winter. At

lower latitudes, air conditioning raises outside temperatures and cools indoors. Due to reduced evaporation cooling from vegetation and forced drainage of rainwater, the urban water balance shifted creating the UHl.

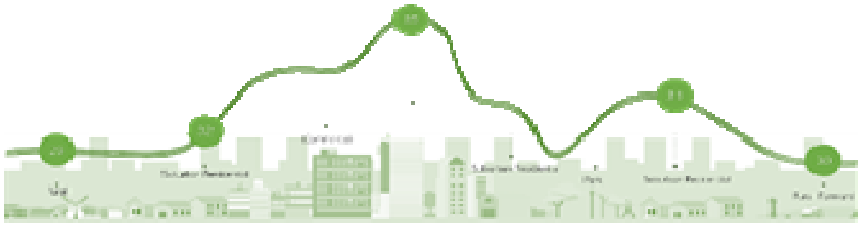

Figure 5: Generalized cross-section of a typical urban heat island. Source: authors.

5 METHODS AND DATA ANALYSIS

The research methodology is aimed at studying urban climate maps and urban heat islands and their mitigation. The various factors affecting urban heat island measurement were identified through various analyses. Analysis of the obtained data was done by using the software Arc Map 10.8. Initial studies have been done on the urban sprawl in the study area. From the built-up, the next study was done on the land surface temperatures of the study area from the data from satellite imagery.

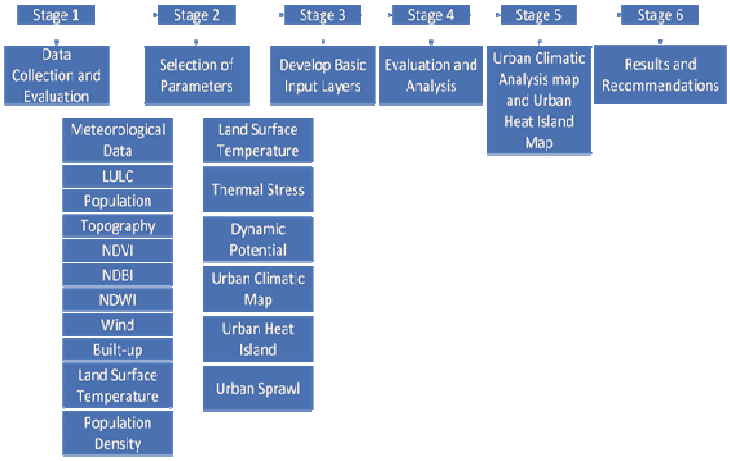

Figure 6: Research methodology. Source: authors.

6 RESULTS AND DISCUSSIONS

6.1 Urban Sprawl

Urban sprawl was studied in 2001, 2011, and 2021. Figure 5 shows that the built-up area has raised considerably in the last two decades. Due to emerging enterprises and commercial facilities, several vacant lands have been built up. Tree cover decreases with urbanization.

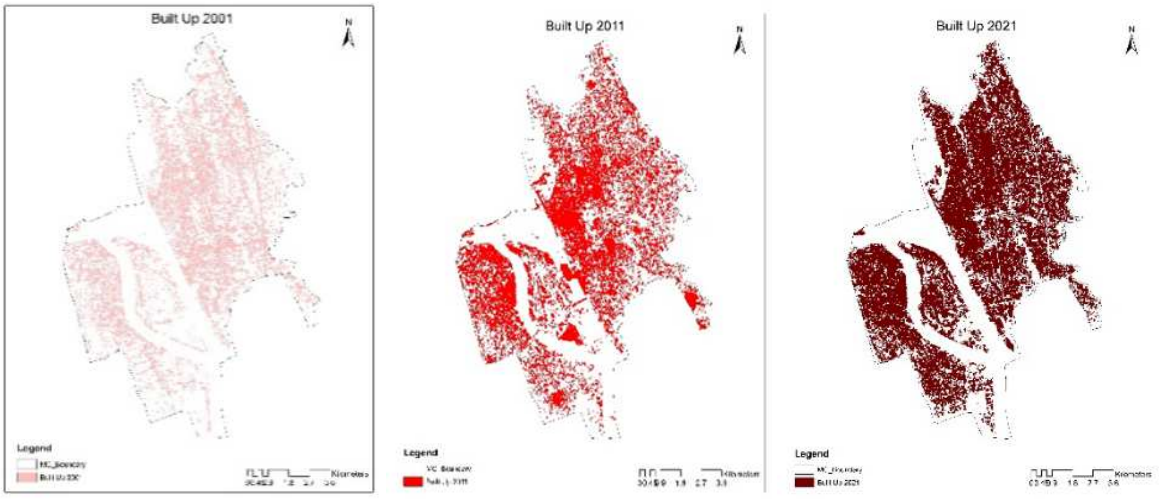

Figure 7 (left and middle): Built-up 200-2011. Source: authors. Figure 8 (right): Built-up 2021. Source: authors.

6.2 Land surface temperature

The radiative skin temperature of the land derived from solar radiation is known as land surface temperature (LST). LST measures the amount of thermal radiance emitted by the land surface where incoming solar energy interacts with and heats the ground or the canopy surface in vegetated areas. The land surface temperature can be significantly influenced by urbanisation. As cities and towns grow, natural landscapes are often replaced with buildings, roads, and other impervious surfaces that absorb and store heat differently than vegetation and soil. This can result in what is known as the urban heat island effect, in which cities have higher temperatures than surrounding rural areas. Kochi's development has had a considerable effect on land surface temperature. According to satellite imagery analysis, the LST in Kochi's urban regions was around 35°C, with a maximum of 36°C, while it was around 31°C in rural areas.

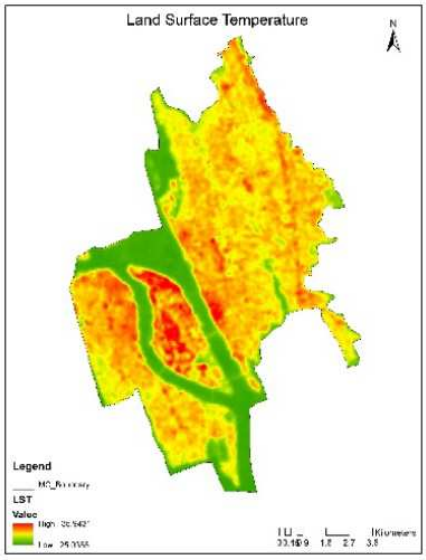

Figure 9. Land Surface Temperature (Source: authors.)

6.3 Urban climate map analysis

Thermal load and dynamic potential maps were used to combine the investigation of the urban climate. To determine the output of the thermal load and dynamic potential, several factors were examined. The urban climatic map shows us which places are sensitive and where climate intervention is needed, indicating high thermal load and low dynamic potentials.

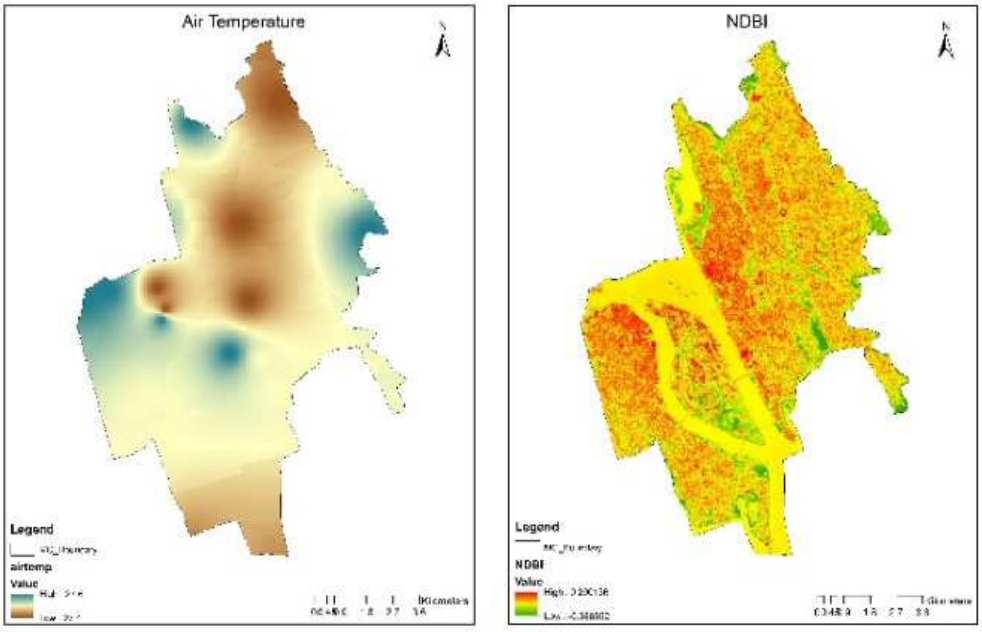

Figure 10: Air Temperature and NDBI

6.4 Thermal Load Map and Dynamic Potential

Thermal load in the context of urban climate refers to the quantity of heat energy created or absorbed by buildings, automobiles, and other sources in the urban environment. Because of the concentration of thermal load, this can contribute to the urban heat island effect, in which metropolitan regions suffer greater temperatures than surrounding rural areas.

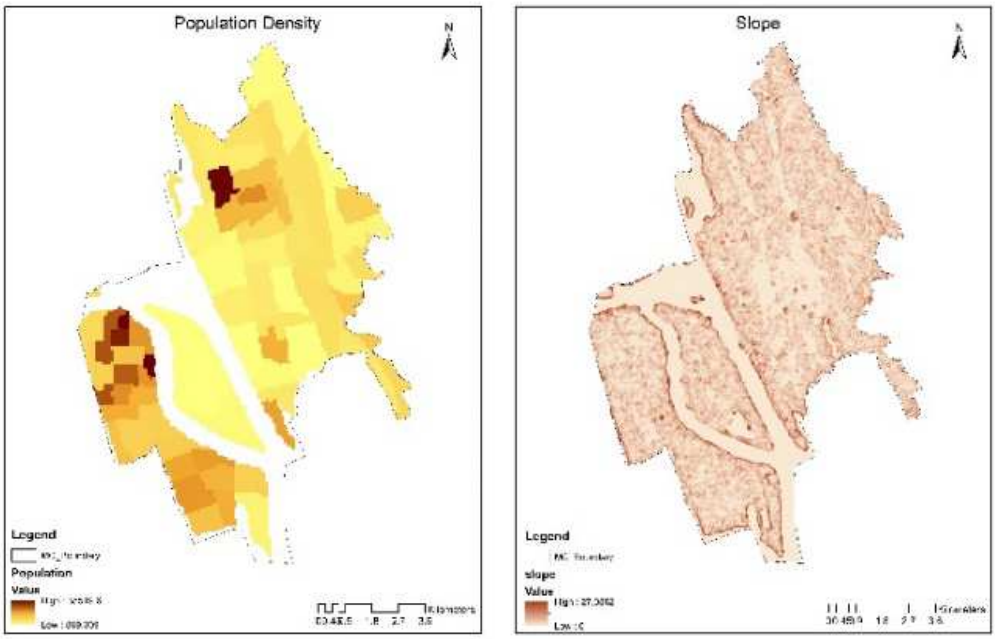

Figure 11: Population Density and Slope. Source: authors.

The capacity of the urban environment to adjust and react to changing circumstances, such as variations in temperature, precipitation, and other meteorological events, is referred to as dynamic potential in the context of urban climate. This can involve using green infrastructure, like trees and green roofs, to offer shading and cooling, using reflecting materials to lessen heat absorption and creating smart buildings that can vary their thermal load based on outside circumstances. The thermal Load and dynamic potential are integrated based on the 9 input factors indicated to produce the synthetic urban climatic map. The characteristics that have a negative correlation with temperature and may be used to better reduce UHI are merged to create a dynamic potential map. The input Layers related to the dynamic potential map is NDVI, NDWM, and Prevailing wind velocity, and the rest to construct a thermal Load map.

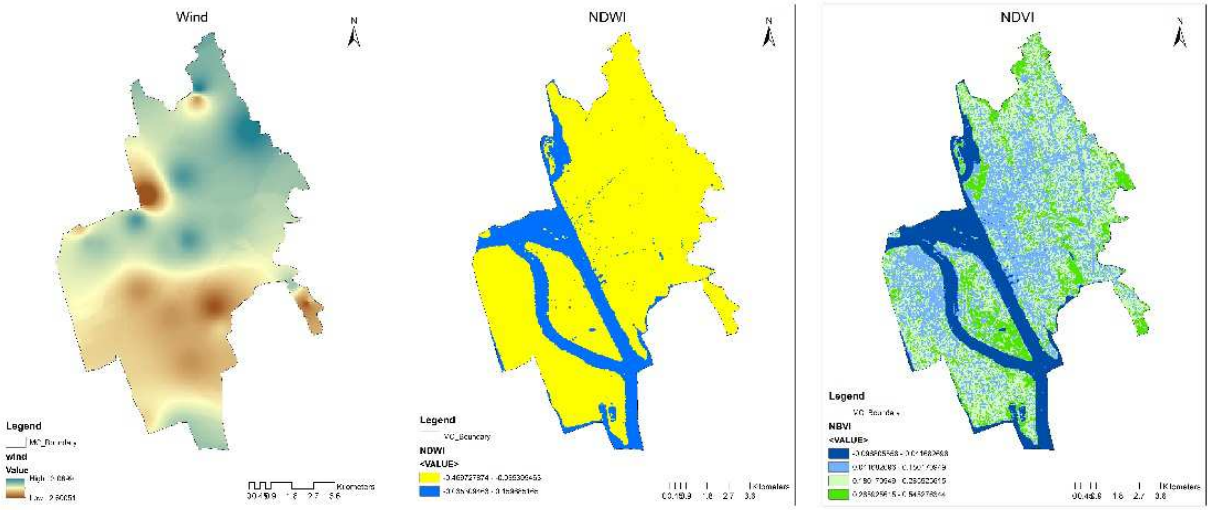

Figure 12 (left and middle): Prevailing Wind and NDWI of the Study Region. Source: authors. Figure 13 (right): NDVI of the Study Region. Source: authors.

6.4.1 Thermal Load Map and Dynamic Potential

The Urban Climatic map has been synergized from the dynamic potential and thermal load values. The map shows the sensitive areas which need planning intervention. The low value of sensitivity areas is those which are less populated. Urban climatic maps can offer important details on the layout of infrastructure, public areas, and buildings. The urban climatic map makes it clear that some areas of Fort Kochi, Vytilla, and some of the eastern sections of the study zone require intervention, such as parks and green spaces, the positioning of buildings to decrease heat gain, and the orientation of streets and buildings to optimize ventilation.

The climate map created is utilized to analyze the urban heat island of the Kochi city region. Parameter evaluation is by assigning scores to them with temperature. Because UHI is defined in terms of temperature, the study's parameters have units and all of them are brought on a common unit.

Parameter	SCORING RANGE	Very low temperature	Low temperature	Moderate temperature	High temperature	Very high temperature
	Score	1	2	3	4	5
LST	Parameter Range	very high comfort	high comfort	moderate comfort	low comfort	very low comfort
	Value	25-27	27-28	28-29	29-31	31-36
NDBI	Parameter Range	very low NDBI	low NDBI	moderate NDBI	high NDBI	very high NDBI
	Value	<-0.23	-0.22--0.15	-0.14--0.078	-0.077--0.0046	-0.0045-0.29
Population Density	Parameter Range	very low population density	low population density	moderate population density	high population density	very high population density
	Value	180-3200	3300-6400	6500-11000	12000-16000	17000-36000
Air Temperature	Parameter Range	very high comfort	high comfort	moderate comfort	low comfort	very low comfort
	Value	27.3-27.364	27.364-27.431	27.431-27.478	27.478-27.529	27.529-27.6
Topography	Parameter Range	very high topography	high topography	moderate topography	low topography	very low topography
	Value	0-0.86	.86-2.4	2.4-4.46	4.46-7.46	7.46-27.09

Table 1 Factors affecting thermal load and their impact on the urban environment.

Parameter	SCORING RANGE	Very low temperature	Low temperature	Moderate temperature	High temperature	Very high temperature
	SCORE	1	2	3	4	5
NDVI	Parameter Range	very high NDVI	high NDVI	moderate NDVI	low NDVI	very low NDVI
	Value	0-0.86	0.86-2.4	2.4-4.46	4.46-7.46	7.46-27.09
NDWI	Parameter Range	very high NDWI	high NDWI	moderate NDWI	low NDWI	very low NDWI
	Value	-0.47--0.264	-0.264--0.18	-0.18--0.076	-0.076-0.054	0.054-0.179
Prevailing wind	Parameter Range	fresh breeze	moderate breeze	gentle breeze	light breeze	light air
	Value	2.6-2.82	2.82-2.89	2.89-2.96	2.96-3.02	3.02-3.12

Table 2 Factors affecting dynamic potential their impact on the urban environment.

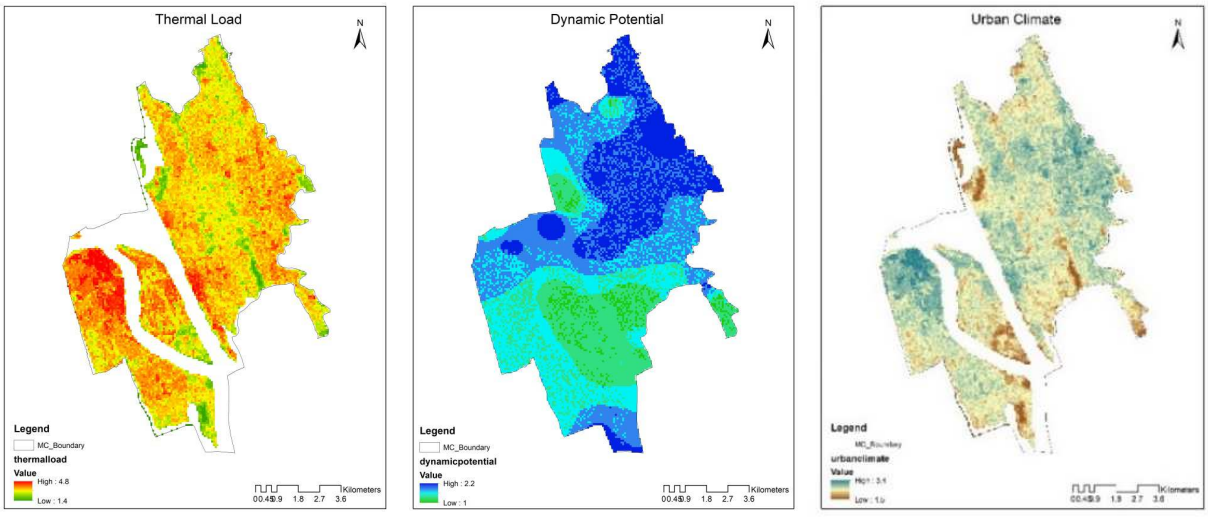

Figure 14 (left): Thermal Load. Figure 15 (middle): Dynamic potential. Figure 16 (right): Urban climatic map. Source: authors.

6.4.2 Urban Heat Island

Urban Heat Island has been generated by utilizing the land surface temperature. According to analysis, Kochi's UHI impact is strong, with temperature disparities between high- and low-built-up regions of up to 4-5°C ranging from 33 to 26 degrees in the city limits. The high population density, urbanization, and development are the primary causes of the temperature increase in Kochi. A rise in the number of structures, paved areas, and automobiles as a result of the city's recent fast expansion has increased the UHI impact. On the environment and people's health, the UHI effect in Kochi has several effects. It might result in higher cooling and air conditioning energy usage, which would raise greenhouse gas emissions and air pollution. The maximum temperature zone is on Willington Island which is a cantonment area.

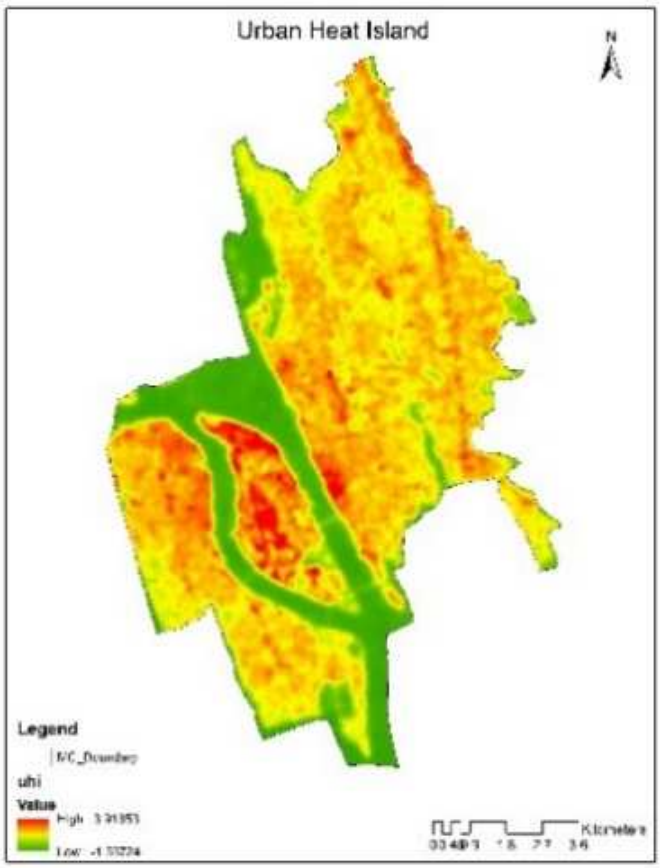

Figure 17:. Urban Heat Island. Source: authors.

7 OBSERVATIONS AND FINDINGS

The Urban Climatic Map and the severity of urban heat islands found in Kochi show the influence of built-up areas and other variables on the creation of heat islands and other climate-sensitive zones in the city limits. The city centre region, which has the highest concentration of anthropogenic activity, was where the intensity was at its peak. In areas of the region that were open and sparsely built, temperatures were lower. The differences between the low and high built-up regions were 4-5 °C due to the pockets of urban heat islands.

8 CONCLUSIONS

Shade trees, shrubs, vines, grasses, and ground cover cool the metropolis. Leaves and branches limit solar energy reaching the canopy. In summer, 10 to 30% of the sun's energy reaches the area under a tree, with the rest absorbed by leaves for photosynthesis and reflected into the sky. Forests and plants "transpire" water through their roots and leaves. Evapotranspiration cools air by evaporating water using air temperature. Evapotranspiration alone or with shade can lower peak summer air temperatures, according to research. The highest air temperatures in tree groves are 5 °C lower than on open land, irrigated agricultural fields are 3 °C lower than bare ground, and suburban areas with mature trees are 2 to 3 °C lower. Cooler than new suburbs without trees, while grass sports grounds are 1 to 2 °C cooler.

Another method is by using high albedo pavements. High-albedo pavement reflects more sunlight and absorbs less heat. High albedo pavement can reduce the urban heat island effect by reflecting more sunlight and absorbing less heat. High albedo pavement can be made using concrete, asphalt, and reflective coatings. White concrete and reflective coatings have albedo values of 0.7 or higher, compared to conventional pavements 0.05-0.15. Permeable pavements allow water to pass through rather than pool. These pavements reduce the urban heat by absorbing less heat. Permeable pavements are usually made of pervious concrete, permeable asphalt, or interlocking pavers with spaces between them. The soil filters and absorbs water that leaks through fissures. Permeable pavements reduce flood risk, stormwater runoff, and the urban heat island effect. Green roofing is another way to reduce urban heat. The vegetative covering on a roof is called a "green roof." Like trees and vegetation, green roofs shade surfaces and cool the air through evapotranspiration. These activities cool the roof and air. Green roofs can be installed on residences, offices, commercial real estate, government, educational, and industrial facilities. Heat islands, generated by multiple hot roofs in a city or suburb, can be reduced by cool roofing. Cool roofing solutions are made of highly reflective and emissive materials that can keep 28-33 °C cooler in peak summer weather. Cool roofs reduce energy usage, air pollution, greenhouse gas emissions, and human comfort but may cost more than standard roofing materials.

Finally the institutional mechanism shall begin with the local need for the mitigation efforts. Subsequently, an Inter-Agency coordination committee needs to be formed for reporting and planning the mitigation strategies for the heat islands. This involves thorough research and analysis of the current urban heat island situation, including an examination of local causes and effects. Countermeasures include reducing anthropogenic heat emissions, improving urban surfaces and structure, lifestyle adjustments, and public participation. Implementation includes improving monitoring, working with local governments, and raising awareness. However, this requires different criteria for analysis viz, change of human behaviour, political actions, economic means, etc., which reflects the practicalities and supplement with scientific knowledge for the use to the living conditions of the study region. Continuous research on causes in dynamic processes, and impacts and information interchange with other regions strengthen the effective implementation mechanism in the institutional governance system. Thus, operational framework stays successful by being reviewed and updated to reflect new research and technology to navigate toeards sustainable mitigation and improving Kochi's urban environment.

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Evaluating the Potential of Vertical Farming Business Models for Sustainable Agriculture and Food Security in Cameroon

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1 ABSTRACT

This research investigates the possibility of using vertical farming business models as a sustainable solution to address issues such, as land degradation, urbanization, and climate change in Cameroon to increase agricultural output and ensure food security. The study highlights gaps in the need for a region-specific customized vertical farming business model and identifies gaps in understanding the economic and environmental feasibility of vertical farming in Cameroon. Qualitative methods, including interviews with stakeholders and content analysis using MaxQDa, were employed for analysis purposes. The research explores the advantages, challenges, barriers, and potential technologies and business models associated with vertical farming in Cameroon. It emphasizes the importance of stakeholder involvement, financial support, government support, favorable policies, sensitization and campaigns, education and training, and overall support for its adoption and profitability. Key findings indicate that vertical farming holds promise for improving food security and sustainability in urban areas of Cameroon. Additionally, aquaponics is identified as a cost-effective technology and model within this context. However, some obstacles need to be addressed to adopt vertical farming in Cameroon. These include high initial costs, technological and infrastructural challenges, the need for supportive/favorable policy frameworks, clear vertical farming policies, education and training, and the urgent need for collaboration among stakeholders. A final model “Vertical Farming Business Model for Cameroon" was suggested which proposes an implementation model specifically tailored to suit local conditions while considering stakeholder expectations. Conclusively it is going to be a very profitable business.

Keywords: Business models, Agricultural sustainability, Food security, Stakeholders, Vertical farming

2 INTRODUCTION

2.1 Background

The issue of food security, in Cameroon is being impacted by the growth of areas and the increasing population, which in turn affects farming practices. Climate change, unrest, and changes in land use exacerbate this situation. To address these challenges vertical farming has emerged as a solution. This innovative approach involves growing crops in stacked layers under controlled conditions to maximize space and resources specifically targeting the constraints faced by agriculture (Fonjong & Gyapong 2021; Kountchou et al., 2021; Kenette et al., 2019; Njuh et al., 2022; Siregar et al., 2022; Sonhafouo Chiana et al., 2022).

This study aims to assess the feasibility of implementing vertical farming business techniques and models in Cameroon as a means to enhance both food security and environmental sustainability when compared to traditional farming and regenerative traditional farming methods. It delves into the aspects of adopting business models for vertical farming within Cameroon's unique context while exploring their potential contributions, to sustainability and food security. By referencing Siregar et al. (2022) this research seeks to address the challenges posed by urbanization, climate change, and other agricultural factors while emphasizing how a vertical farming business model can serve as a solution tailored to Cameroon's circumstances.

2.2 Research Gap and Objectives

Cameroon is currently facing food security challenges because of growth and agricultural difficulties. To address these issues vertical farming has been recognized as a solution. However, there are some challenges related to adaptation, environmental factors, and regulations that need to be addressed (Appolloni et al.,

2020; Baumont de Oliveira et al., 2022). It is crucial to develop localized models and understand the impact to effectively tackle these challenges (Araújo et al., 2021; Martin & Bustamante 2021; Tabe Ojong et al., 2023).

Due, to climate change and urbanization traditional agriculture in Cameroon is struggling. This has led to an increasing need for approaches like farming under controlled conditions, which can ensure both food security and sustainability (Fonjong & Gyapong 2021; Kountchou et al., 2021; Kenette et al., 2019; Njuh et al., 2022; Siregar et al., 2022; Sonhafouo Chiana et al., 2022).

The research findings highlight a gap in a region-specific business model for vertical farming in Cameroon. Existing studies primarily focus on concepts derived from countries, which may not fully align with the circumstances of a developing nation, like Cameroon (Nchu et al., 2019; Sneyd, 2013).

It highlights the significance of developing business models for vertical farming that consider Cameroon factors, such, as available resources, climate conditions, crop preferences, and local market dynamics. This emphasizes the need for customized solutions that address Cameroon's circumstances.

Examining the feasibility of vertical farming business models in Cameroon is crucial for ensuring sustainability. Research objective one is to evaluate the advantages, challenges, and obstacles associated with vertical farming in comparison to traditional farming methods. Research objective two seeks to identify technologies and models that can be applied in Cameroon. The goal is to provide insights not for Cameroon but also, for other Sub-Saharan African countries facing similar issues related to urbanization and food security.

3 LITERATURE REVIEW

3.1 Food Security in Cameroon

Ensuring that Cameroon has food is extremely important because it directly affects the well-being and livelihoods of its people. In this section we will take a look, at why food security is so crucial, especially considering the challenges related to agriculture and the various factors that impact both food production and access. Furthermore, we will delve into the principles and techniques of vertical, farming, business models, and successful vertical farming examples. Lastly, we will discuss our plans to address any existing gaps through a framework.

3.1.1 Overview of food security

Food security encompasses the aspects of ensuring that a specific population has access, to nutritious food. This includes factors like food production, distribution, and consumption (Ronzhin & Savel'ev 2022; Saint Ges et al., 2022). In the context of Cameroon, where providing reliable food for its people is a top priority (Mkong et al., 2021; Sikod, 2007) addressing the issue of food provision becomes even more vital due to rapid population growth, particularly in urban centers such as Douala and Yaoundé. Achieving food security, in Cameroon is complex. Influenced by urbanization changing habits and economic disparities (Njuh et al., 2022; Sonhafouo Chiana et al., 2022). To effectively develop strategies and policies to tackle these challenges it is essential to have an understanding of the aspects associated with food security (Suh et al., 2023).

3.1.2 Agricultural Sustainability Challenges

In Cameroon, there are challenges when it comes to establishing agricultural practices, which are vital, for ensuring food security. The changing climate has disrupted weather patterns making it increasingly difficult for farmers to anticipate and adapt to the conditions for crop growth (Adams et al., 2022). Additionally, conventional farming methods face problems due to soil degradation leading to reduced fertility (Fonjong & Zama 2023; Kenette et al., 2019). Furthermore, factors like urbanization and other influences are causing farmland availability to shrink, posing an obstacle to maintaining levels of food production (Baumont de Oliveira et al., 2022). To overcome these difficulties, it becomes essential to implement farming techniques that can effectively address and mitigate these issues (Santini et al., 2021; Tabe Ojong et al., 2021). These challenges highlight the importance of adopting approaches in the field of food production (Ntsama et al., 2020; Saad et al., 2021).

3.1.3 Factors Affecting Food Production and Access

Several factors impact the production and accessibility of food in Cameroon. One crucial concern is the harvest losses, which can be attributed to inadequate storage facilities, transportation challenges, and infrastructure issues (Fungo et al., 2023; Nchu et al., 2019). These losses particularly affect the country's ability to meet the increasing needs of its population (Biancone et al., 2022). Additionally, declining soil fertility plays a role in determining productivity. To maintain production levels, it becomes necessary to embrace techniques and technologies that can address this issue. (Blom et al., 2022; Nchu et al., 2019). The scarcity of land due to expansion primarily contributes to constraint food production (Thomson, 2022). Farmers often encounter difficulties in cultivating plots of land posing a challenge in meeting the growing demands (Hutton et al., 2021; Sneyd, 2013).

3.2 Existing Initiatives and Policies

Cameroon understands the significance of prioritizing food security and agricultural sustainability. The government has taken steps to address these challenges by implementing policies and initiatives (Fonjong & Gyapong 2021; Kenfack, 2017). These efforts include programs aimed at increasing production, improving infrastructure, and advocating for farming practices (Deepthi et al., 2021). The National Agricultural Investment Plan (NAIP) aims to enhance output develop infrastructures and provide support to smallholder farmers (Fonjong & Gyapong 2021; Siregar et al., 2022). Moreover, there are initiatives to promote climate farming practices and encourage the widespread adoption of sustainable approaches, in agriculture (Marius et al., 2023; Ngetleh et al., 2023)

3.3 Vertical Farming

3.3.1 Definition and Principles

Vertical farming focuses on maximizing resource efficiency and promoting sustainability by utilizing technologies such, as hydroponics, aeroponics, and aquaponics to control conditions. These techniques enhance plant growth and productivity (Ngetleh et al., 2023; Siregar et al., 2022; Ambagna et al., 2012; Chimi et al., 2022; Baumont De Oliveira et al., 2021; Nana et al., 2022; Wood et al., 2020). Its advantages are particularly evident in confined spaces where vertical designs optimize land usage (Chimi et al., 2023; Tabe Ojong et al., 2023).

3.3.2 Advantages of Vertical Farming

Vertical farming enhances agricultural productivity, enabling controlled environments for faster plant growth and higher yields (Martin & Bustamante 2021; Carine, 2019; Tabe Ojong et al., 2023). It significantly reduces water use through recirculation techniques and allows for year-round cultivation, independent of weather (Naranjani et al., 2022). Additionally, it minimizes pesticide reliance, supports sustainable farming (Avgoustaki & Xydis 2020), and reduces transport emissions by enabling closer-to-consumer farming locations (Ntsama et al., 2018; Appolloni et al., 2020).

3.3.3 Disadvantages and Challenges

Vertical farming, while promising, comes with challenges like high setup costs for infrastructure and technology (Ntsama et al., 2018; Oh & Lu, 2023), increased energy demand for maintaining the controlled environment (Tambi et al., 2017; Sotamenou & Parrot, 2013), and navigating complex regulatory frameworks in urban settings (Awazi, 2022; Kalantari et al., 2018). These factors necessitate careful planning and management to ensure the sustainability and feasibility of vertical farms.

While vertical farming enables the cultivation of various crops, challenges arise with larger staple crops like maize and wheat due to spatial requirements (Fonjong & Gyapong 2021; Sneyd, 2013). Success in vertical farming demands expertise across horticulture, engineering, and technology, with knowledge gaps posing potential obstacles (Jeh Mkong, 2018; Sogang & Monkouop, 2022). Yet, its resource efficiency and ability for year-round production align well with addressing agricultural issues in regions like Cameroon (Sonwa et al., 2019).

3.3.4 Vertical Farming Technologies

Vertical farming employs technologies such, as hydroponics aeroponics, and aquaponics. Each of these techniques offers advantages. Hydroponics is gaining popularity due, to its cultivation of plants without soil using water solutions. It allows for control over nutrients. Promotes faster plant growth, particularly suitable for leafy greens, herbs, and certain fruits (Jeh Mkong, 2018; Tabe Ojong et al., 2023; Mir et al., 2022; Sonwa et al.,2019)

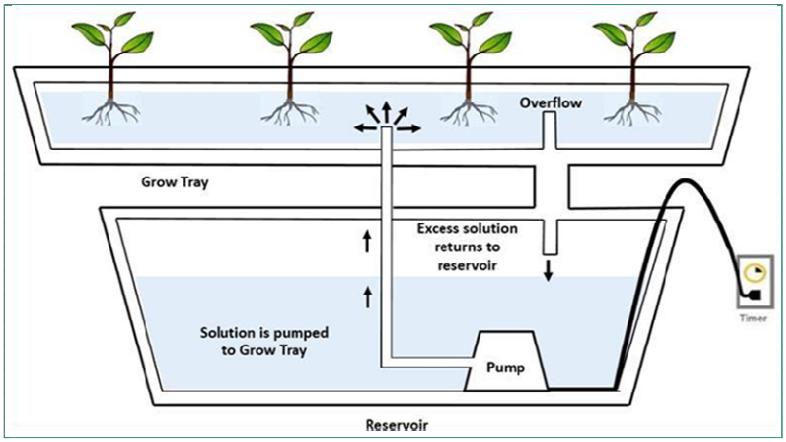

Figure 1: Diagram of a hydroponic system (Gupta & Ganapuram 2019, P.4)

Aeroponics improves water efficiency by misting nutrients onto plant roots in the air. This method optimizes oxygen supply and water usage (Bayiha et al., 2019; Kountchou et al., 2021). Aquaponics combines fish cultivation（aquaculture） with hydroponics, where fish waste nourishes plants while the plants purify the water for the fish. This creates a cycle of resource utilization and waste reduction (Bayiha et al., 2019; Ewoukem et al., 2017). The choice of farming technology depends on factors such as crop type, available resources, and location (Ewoukem et al., 2017; Awazi, 2022; Gerrewey et al., 2022).

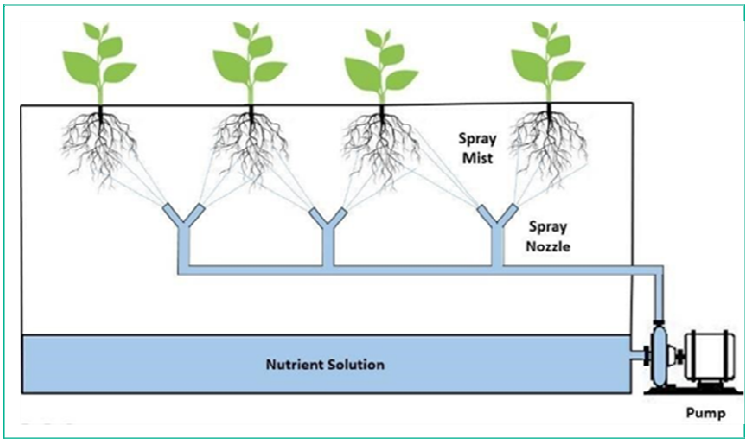

Figure 2: Diagram of an aeroponic system (Gupta & Ganapuram 2019, P.5)

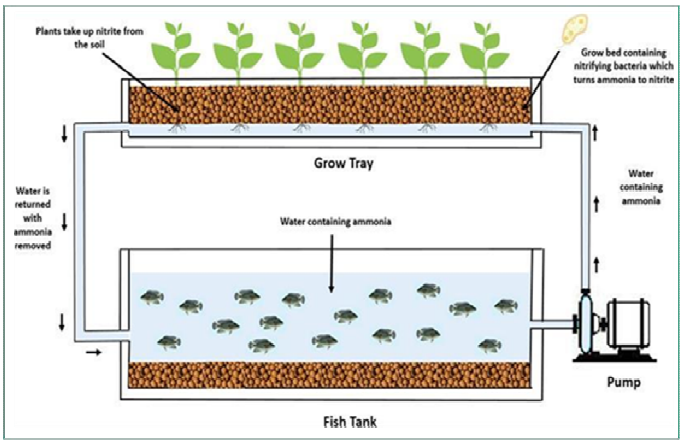

Figure 3: Diagram of an aquaponics system (Gupta & Ganapuram 2019, P.6)

3.3.5 Vertical Farming Business Models

Vertical farming models vary based on cultivator goals and resources, from individual operations funded by stakeholders to collaborative ventures with agribusinesses. The choice of the model influences management, funding, and expansion strategies, which are crucial for overcoming vertical farming's challenges. Financial support can come from private investors, startup capital, and government grants (Jeh Mkong, 2018; Ntsama et al., 2018; Sotamenou & Parrot, 2013; Awazi, 2022; Kalantari et al., 2018; Kenfack, 2017; Sogang & Monkouop, 2022; Sonwa et al., 2019; Mkong et al., 2021; Mir et al., 2022).

Aquaponics Business Model Framework

The Aquaponics business model combines fish farming and hydroponics, in systems, which is particularly advantageous in areas with limited water and crowded urban environments. It maximizes the use of water and space by creating a relationship between fish and plants. The plants utilize the waste produced by the fish as nutrients while also purifying the water. This model can be adapted for garden setups or scale commercial operations providing a sustainable solution for food production (Nana et al., 2022; Mir et al., 2022; Sonwa et al., 2019).

Araújo et al. (2021) have presented a framework for an aquaponics business that considers factors such as environmental, political, economic, social, technological, legal, and ecological aspects to ensure success. This framework includes strategies for market penetration components of the value chain, synergy among system elements considerations for investments, and analysis of viability with emphasis on risk management generating cash flow, and meeting stakeholder expectations. Financing strategies based on analysis are implemented to guarantee returns on investment for all parties with a focus, on ventures that carry lower risks (Brigham et al., 2014).

The structure developed by Araújo et al. (2021) aims to integrate sources and components while emphasizing not only their incorporation but also their interrelationships.

The primary objective of this method is to prioritize profitability. It does so by considering factors such, as the choice of fish and plant species, the type of system used, and the sales channels employed. This highlights the significance of comprehending how different components work together in aquaponics business planning.

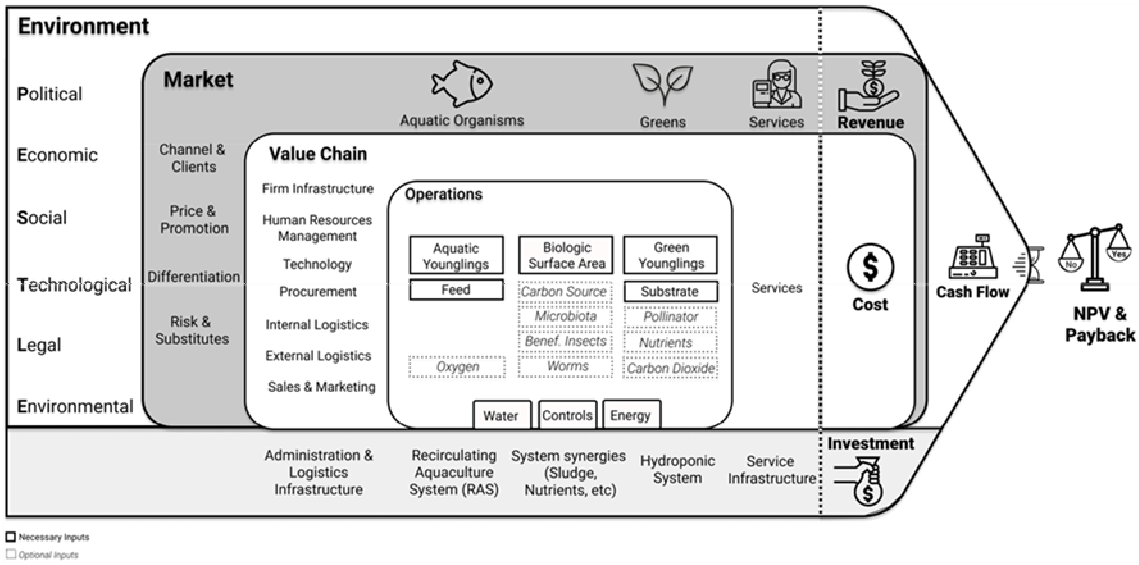

Figure 4: Making Aquaponics a Business Framework. (souce: Araújo et al. 2021)

Business Model Canvas

The Business Model Canvas (BMC), created by Alexander Osterwalder in 2008 and detailed in Osterwalder & Pigneur (2010), consists of nine components providing a comprehensive overview of a business's key drivers. Pölling et al. (2017) noted BMC's suitability for strategic management in vertical farming, highlighting its ability to outline value creation, relationships, and success factors. BMC aids in identifying success components, obstacles, competitor analysis, and in generating new ideas, widely used by entrepreneurs for evaluating business concepts, as supported by Henriksen et al. (2012).

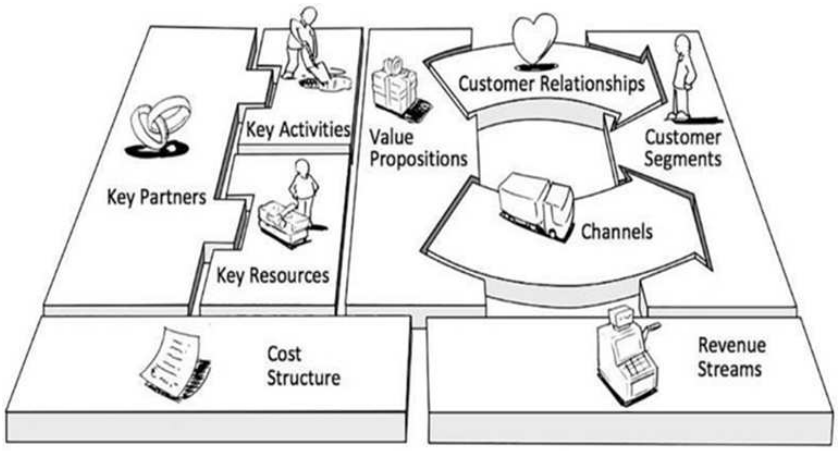

Figure 5: Business Model of Canvas (source; Osterwalder and Pigneur, 2010(page18-19))

The Business Model Canvas (BMC) by Osterwalder and Pigneur (2010) outlines nine key elements: customer segments, value proposition, channels, client relationships, revenue streams, activities, key resources, partners, and cost structure. These components collectively facilitate a strategic overview for businesses to tailor products/services, understand customer relations, manage resources, and outline financial structures. BMC's practical application in enterprises like Techno Farm in Japan showcases its effectiveness in crafting and enhancing business strategies (Aruni et al., 2019).

Vertical Farming as a Service (VFAAS) Model

This emerging business model offers vertical farming solutions as a service, allowing customers to access fresh agricultural products without investing in infrastructure. Enterprises manage crop cultivation, offering subscriptions for produce or investment opportunities in specific crops' cultivation. This approach minimizes customers' financial commitments while ensuring access to locally produced fresh products (Nana et al., 2022).

B2B Vertical Farming Model

B2B models in vertical farming involve providing technology and solutions to other businesses, with a growing number of companies specializing in systems, LED lighting, hydroponics, aeroponics, and data analytics. These companies support the vertical farming industry by servicing both new and established enterprises, contributing to the sector's growth (Baumont de Oliveira et al., 2022; Thomson, 2022).

3.3.6 Successful Case Studies

Analysing vertical farming case studies, like Sky Greens in Singapore for leafy greens production, and Japan's year-round vegetable cultivation, demonstrates vertical farming's potential to enhance food security and sustainability (Mir et al., 2022; Sonwa et al., 2019; Sikod, 2007). Additionally, advancements by Panasonic in Singapore highlight technological progress in the field (Bayiha et al., 2019; Kountchou et al., 2021; Ewoukem et al., 2017; Gerrewey et al., 2022). These studies support vertical farming's feasibility and adaptability for countries like Cameroon facing similar agricultural challenges.

3.3.7 Significance of a Vertical Farming Business Model Framework in Cameroon

In Cameroon, vertical farming addresses food security and sustainability amid urban growth, offering a controlled environment for agriculture, enhancing crop productivity, and reducing transport costs. This approach supports local food production, reduces import reliance, and adapts to Cameroon's diverse climates for year-round cultivation (Hutton et al., 2021; Oh & Lu, 2023; Fungo et al., 2023; Jeh Mkong, 2018; Sonwa et al., 2019; Kalantari et al., 2018; Sotamenou & Parrot, 2013).

3.4 Profitability in Vertical Farming Business Models

Vertical farming optimizes space and resources, increasing financial viability through year-round crop production and automation to reduce labor costs. Customization for specific crops targets niche markets, enhancing profit margins. Collaborations with tech firms and researchers to further profitability by staying ahead in innovation and compliance (Suh et al., 2023; Tabe-Ojong et al., 2021, 2023; Fonjong & Gyapong, 2021; Sneyd, 2013).

3.5 Comparative Analysis of Business Models

Assessing vertical farming models highlights their adaptability to Cameroon's agricultural context, influenced by strategy, technology, and market specifics. Adapting models to local conditions, climate, market demands, and technology, is critical. Direct application of international models requires assessing their relevance to Cameroon, considering resilience, local market needs, and community engagement. Profitability varies by focus, emphasizing the need for models responsive to Cameroon's unique agricultural environment (Jeh Mkong, 2018; Bayiha et al., 2019; Sonwa et al., 2019).

3.6 Initial Framework for Vertical Farming Business Model in Cameroon

This study aims to evaluate the feasibility of vertical farming business models as a solution to enhance food security in Cameroon. It emphasizes the need to adapt to the conditions of Cameroon and addresses gaps in existing literature. To achieve this a business model framework is proposed by combining "Making Aquaponics a Business; A Framework", with "the Business Model Canvas" specifically tailored for the climates of Cameroon. The framework is designed to address environmental and resource challenges by incorporating models that engage stakeholders effectively and implementing strategies for market and consumer alignment within Cameroon.

The vertical farming framework for Cameroon prioritizes aspects such as maximizing space efficiency adopting technologies, managing resources effectively, and fostering community engagement. Its main goal is to meet stakeholder expectations while adapting to the climate available resources and economic conditions to ensure profitability. This model highlights the importance of community involvement and cost-effective automation methods. Selecting crops based on market demand as factors, for long-term success (Mir et al., 2022; Maleki, 2022; Santini et al. 2021; Saad et al., 2021).

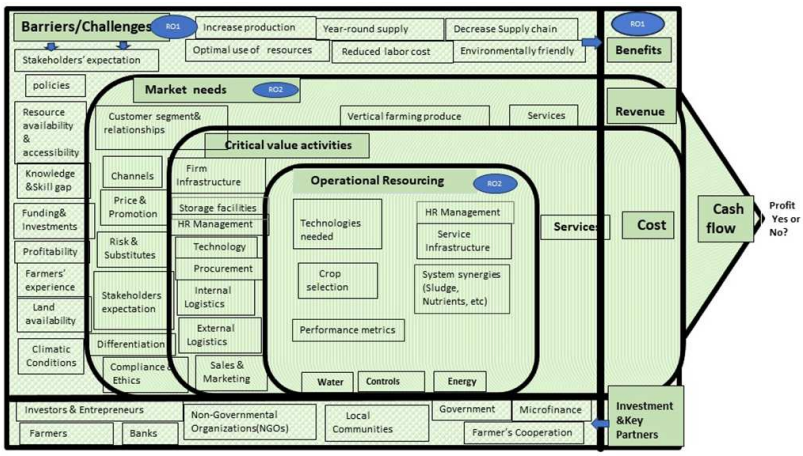

Figure 6: Initial conceptualization based on Araújo et al,2021 and Osterwalder & Pigneur, 2010

3.7 Summary of Literature

The research underscores a critical gap in understanding vertical farming business model feasibility in Sub-Saharan Africa, notably Cameroon. It identifies a significant shortfall in comprehensive studies addressing specific challenges and prospects for vertical farming in Cameroon, highlighting overlooked aspects like market demand, climate adaptability, stakeholder expectations, profitability, and regulatory impact. This gap suggests a need for targeted research to unlock vertical farming's potential in enhancing food security and agricultural sustainability in the region.

4 METHODOLOGY

The study adopts a qualitative research methodology, underpinned by an interpretivist philosophy, to explore the feasibility of vertical farming business models in Cameroon. It combines deductive and inductive approaches, drawing on existing theories and allowing new insights to emerge from the data collected through interviews and observations. This mixed-method approach facilitates a comprehensive understanding of vertical farming technologies and models suitable for Cameroon, emphasizing the subjective nature of research findings as influenced by the researcher's interpretations (Nur, 2020; Byrd, 2020; Cuthbertson et al., 2020; Mayring, 2004; Tyagi et al., 2021).

Data collection centered on interviews, with 15 carefully crafted questions informed by recent literature and expert feedback, ensuring content validity. The study engaged with individuals knowledgeable about Cameroon's agricultural sector, including farmers and investors, employing non-probability and purposive sampling techniques complemented by snowballing. Online interviews conducted via Zoom and WhatsApp from January 6th to 16th, 2024, facilitated participation from respondents both within and outside Cameroon, leveraging technology that is online software and websites for efficient transcription and documentation of the data collected.

For data analysis, the study utilized MAXQDA software to perform qualitative content analysis, applying both concept-driven and data-driven coding strategies. This methodology enabled the identification of key themes and insights pertinent to vertical farming business in Cameroon, drawing on initial codes derived from research goals and allowing for the emergence of new categories. The use of MAXQDA enhanced the analytical rigor of the study, providing a structured framework for coding, quantification, and mapping relationships between codes, thus effectively addressing the research questions posed (Van der Walt, 2020)

4.1 Ethical Considerations

The research adhered to ethical standards by obtaining informed consent from all participants, ensuring they understood the study's procedures. Participant identity and personal information were kept confidential, with only the researcher accessing the data to maintain privacy and security throughout the study.

5 PRESENTATION OF FINDINGS

5.1 Benefits, Challenges, and Barriers of Vertical Farming Business in Cameroon

5.1.1 Benefits of Vertical Farming

The respondents provided insights into the advantages of vertical farming in Cameroon. Many of them highlighted many potentials which include increased production and yields, efficient water management, and year-round cultivation in controlled environments. Operating in this way reduces reliance on variations and promotes crop diversity. Additionally, it minimizes transportation costs encourages community involvement drives advancements, and supports eco-friendly practices. These findings emphasize the potential of vertical farming businesses to address challenges related to urban space, water scarcity, and food security in Cameroon. Therefore, implementing vertical farming businesses can contribute to sustainability efforts(agriculture, food security, environmental, etc..) as well as technological innovation in the agricultural sector.

Vertical Farming benefits extend beyond considerations such as water management and conservation. It also serves as an alternative to farming methods by mitigating issues like deforestation, soil erosion, land disputes, and greenhouse gas emissions. In addition to conserving resources, it optimizes land usage which addresses land scarcity while promoting sustainability, within urban areas (R1, R2, R3, R5, R7, R8&R12).

The respondents also highlighted how vertical farming can help overcome challenges faced by agriculture practices in Cameroon. Specifically mentioned is the shorter distribution chain offered by vertical farming which reduces transportation needs while improving produce quality. This approach is considered a solution for areas addressing the challenges of logistics and ensuring a supply of fresh produce. Additionally, vertical farming is recognized for its ability to save time and financial resources while reducing reliance on inputs such as herbicides and pesticides. This has been particularly highlighted during COVID-19. These findings indicate that vertical farming offers an alternative to overcome the obstacles faced by farming methods in terms of logistics and yield.

Respondents further emphasized the importance of distribution and partnerships with retailers to ensure the financial sustainability of vertical farming businesses in Cameroon. They highlighted how customer demand impacts the market and expressed views on the increasing popularity of vertical farming. They also acknowledged its benefits, including access to sources of fresh produce, and improved financial sustainability through continuous production. These insights highlight the significance of relationships and market responsiveness, for vertical farming ventures.

5.1.2 Challenges and Barriers

Respondents highlighted both the benefits and challenges of vertical farming businesses in Cameroon, noting skepticism due to traditional farming loyalty and market dynamics issues like customer demand and high costs leading to higher cost prices for vertical farming products. Concerns were raised about competition affecting profitability and the lack of regulatory frameworks. Emphasizing the balance between vertical farming's advantages, and market and legal challenges is deemed crucial for its successful integration and financial sustainability in Cameroon.

Respondents identified key financial, technological, and infrastructural challenges for vertical farming in Cameroon, including high initial costs, especially for artificial lighting and energy use, and issues with technology access, funding, and resource availability. The need for specific expertise and stable infrastructure such as electricity and water supply was also highlighted since it is unstable and unreliable, underscoring the complexities of implementing vertical farming in the region. These insights stress the importance of addressing these barriers to harness vertical farming's potential for sustainable agriculture in Cameroon.

The challenges for vertical farming in Cameroon are diverse, including financial, technological, and infrastructural issues. Solutions like outsourcing alternative power sources, as suggested by one of the respondents, could mitigate the barriers and ensure the implementation of vertical farming business models in Cameroon and it is essential to address various challenges. Vertical farming holds potential in terms of enhancing food security and sustainability in Cameroon.

During the interviews respondents further pointed out several regulatory and policy obstacles that vertical farming faces in Cameroon. These include unfavorable taxes, the absence of frameworks and financial supports, incentives as well as a lack of clear regulations. Additionally, concerns were raised about resistance from farming communities. The complex landscape of these challenges must be navigated effectively to foster the success of farming in the region.

Lastly, one major challenge identified by respondents across interviews is the knowledge and skill gap associated with vertical farming in comparison to traditional farming practices in Cameroon. This gap arises due to its novelty and technological demands. Bridging this gap is crucial for the adoption and implementation of vertical farming technologies and models in Cameroon. It requires training programs, education initiatives, and adjustments within the educational curriculum to incorporate vertical farming.

The challenges faced by vertical farming businesses in Cameroon include knowledge gaps, lack of awareness, insufficient educational support, unclear policies, and financial constraints. All these obstacles could hinder the adoption and success of vertical farming practices in Cameroon. Comprehensive strategies must be developed promptly to address these issues effectively.

Even though, t these obstacles could be addressed soon, the local farmers and investors will smoothly adopt vertical farming businesses as an alternative for more sustainable agricultural practices for some crops for higher profits and food security. However, Vertical farming cannot replace traditional farming 100 percent in Cameroon anytime soon, especially as Cameroon's staple crops like maize, cocoa, plantains, and bananas haven't been investigated thoroughly to know if they can do well in vertical farming technology now.

5.2 Optimal Vertical Farming Technologies and Vertical Farming Business Models

5.2.1 Vertical Farming Technologies and Adoption

Here the respondents were asked about the technologies they are familiar with and how well the technologies have been adopted and accepted.

Vertical Farming Technologies

Respondents across the study demonstrated a strong familiarity with vertical farming technologies, particularly favoring aquaponics also for its traditional practices in Cameroon, cost-effectiveness, and suitability in Cameroon's climate. Aquaponics was noted for its year-round profitability despite dry season challenges and stands out as a sustainable method for fish and vegetable cultivation. Hydroponics also gained attention for its resource efficiency and adaptability to local conditions. The need for alternative water sources during dry seasons and considerations for regional characteristics underline the importance of

tailored approaches. Greenhouse farming was mentioned as another prevalent method, indicating a diverse technological landscape in Cameroon's vertical farming sector.

Conclusively, aquaponics stands out as the favorable vertical farming technology in Cameroon, reflecting the emphasis on sustainable practices suited to local conditions. This method demonstrates the importance of adapting farming techniques to regional needs and efficient resource utilization.

Acceptance and Adoption

The adoption of vertical farming technologies in Cameroon varies, with enthusiasm and acceptance among several farmers for its potential to reduce costs and improve efficiency, particularly through integrated systems like aquaponics. However, overall acceptance is slow, attributed to the novelty of the technology and challenges such as energy costs and a lack of familiarity. Skepticism also exists due to loyalty to traditional farming practices and a general reluctance to adopt new methods without proven benefits, others also mentioned lack of awareness is the cause of the slow acceptance, underscoring the need for increased awareness and education to foster wider acceptance and implementation of vertical farming technologies.

Vertical Farming Business Models

The Aquaponics business model is widely favored among respondents as a cost-effective vertical farming model in Cameroon, noted for reducing production and transportation costs, enhancing resource accessibility, and supporting climate resilience. It combines fish and crop production, promoting water recycling and integration with local practices. Some respondents also recognize the potential of aeroponics and hydroponics for their space efficiency and resource utilization. Emphasis is placed on renewable energy to lower operational costs, with aquaponics praised for its environmental benefits and alignment with local materials and practices for long-term scalability.

5.3 Stakeholders Expectation

5.3.1 Expected support for a vertical farming investment.

The insights emphasize the necessity for government support, partnerships, and educational initiatives to advance vertical farming in Cameroon. Key areas include policy development, financial incentives, infrastructure improvement, and raising public awareness. Stakeholders stress the importance of government flexibility & support, community involvement, and access to finance. The consensus underlines the need for a collaborative approach, incorporating government, private sector, and educational institutions to create a conducive environment for vertical farming businesses, highlighting the crucial roles of sensitization, supportive policies, and resource availability in driving adoption and success.

5.3.2 Opportunities and uncertainties of the vertical farming business

Experts expressed optimism about the potential of vertical farming business in Cameroon to boost food production. They highlighted benefits, such as year-round cultivation, water conservation, job creation, and increased profits. The experts also emphasize the opportunities for market differentiation, growth, sustainable food production, and addressing food shortages. They believe that cultivating high-value diverse crops and reducing distribution chains are vital for ensuring the success and sustainability of farming in the region. In summary, they see a range of opportunities in vertical farming in Cameroon including maximizing production all year providing fresh and high-quality produce, shortening distribution chains for better availability of fresh produce making efficient use of land and water resources while being environmentally friendly.

While vertical farming business models offer promising prospects in Cameroon it is not without challenges and uncertainties. Respondents raised concerns about costs, market dynamics, the unreliability of resources needed for vertical farming operations as well as regulatory complexities. They also acknowledge the novelty of this approach which brings some unpredictability to the market as well as potential pollution risks and demands on resources. Additionally noted were energy costs and political instability that could pose barriers to its success. Addressing these issues will be crucial to unlock the potential of vertical farming business models in Cameroon. It will require efforts to increase market acceptance through regulations and support mechanisms.

5.3.3 Financial Feasibility

Respondents offered insights into evaluating the financial feasibility of vertical farming in Cameroon, emphasizing market analysis, financial support, government involvement, crop selection, and social and environmental considerations. Key points include the importance of understanding market demand, consumer preferences, and climate suitability, alongside the necessity for comprehensive feasibility studies. Financial challenges, the need for collaboration, and the potential for profitability with the right strategies were also discussed, indicating a positive outlook for vertical farming's financial viability compared to traditional methods.

5.3.4 Policies and Regulatory Changes

Respondents emphasized the need for supportive policies for vertical farming in Cameroon, focusing on financial support, resource management, education & training, market dynamics, and partnerships. They advocate for tax breaks, incentives, grants, low-interest loans, infrastructure improvements, educational programs, market access facilitation, and collaborative initiatives between government, industry, and communities to foster vertical farming businesses' adoption. These strategies aim to address challenges like high initial costs, market acceptance, unreliability of resources, lack of awareness, and knowledge gaps, highlighting a holistic approach to promoting sustainable agriculture through vertical farming.

6 DISCUSSION AND CONCLUSION

6.1 Discussion

The study effectively addresses gaps in research on vertical farming business models in Cameroon, highlighting its potential benefits and challenges through expert insights that close the gap which was identified as the lack of research specifically examining the potential benefits, challenges, and barriers associated with adopting vertical farming in Cameroon (Jeh Mkong, 2018; Sonwa et al., 2019). The respondents' feedback (R1-R12) has been synthesized, revealing key benefits such as increased production, water efficiency, and year-round crop availability, alongside challenges including high initial costs and energy requirements, which align with literature findings (Kalantari et al., 2018; Ntsama et al., 2018). Notably, respondents emphasized the barriers of high startup expenses, particularly for infrastructure and energy-intensive systems required for controlled environment agriculture, mirroring concerns highlighted by Tambi et al. (2017). It offers solutions to land-use conflicts, potentially easing tribal tensions by reducing reliance on traditional farming spaces (R12), and can boost Cameroon's economy and food self-sufficiency through shorter supply chains and enhanced crop diversity (R3, R9, R1, R4, R5, & R12). However, it faces significant challenges including political instability, regulatory uncertainties (R1 & R9), and environmental concerns like urban pollution and infrastructure deficits (R4, R1, R4, R5, & R7), which were not extensively addressed in existing literature. These findings highlight both the transformative potential of vertical farming in Cameroon and the critical need for supportive policies and infrastructure to realize its benefits fully by enhancing food security, environmental sustainability, and economic growth.

Respondents emphasize the suitability of aquaponics and hydroponics as the favorable model and technology. The need for supportive policies, education and training, financial incentives, government support, and the importance of stakeholder collaboration for the successful adoption of vertical farming. However, this indicates a thorough emphasis on education and training to be carried out for local farmers and investors in vertical farming businesses to gain skills and knowledge on vertical farming and also increase experts in vertical farming.

The study proposes a tailored vertical farming business model for Cameroon, considering the unique socio-economic and environmental context, aiming to guide future implementations and policy formulations. See Figure 9. The final model which is the "Vertical Farming Business Model for Cameroon" presents the combined and condensed findings. This model also closes the gap that was noted by Nchu et al., & Sneyd which was earlier discussed in the literature

The final model integrates insights from expert interviews on vertical farming business in Cameroon, aligning innovative findings that is the inductive findings that were not discussed in the literature (coded in blue) with literature review insights that is the deductive findings (in black) for localized context adaptation. It emphasized stakeholder involvement, government support, sensitization & campaigns, education &

training, and financial incentives as pivotal for adoption and profitability. Technological adaptation through HR management emphasizes education and training. Operational resources focus on aquaponics as the preferred technology, the model also highlighted the urgent need for comprehensive stakeholder cooperation(cooperation of all key partners) to ensure fast adoption and higher profit margins compared to traditional farming methods in Cameroon.

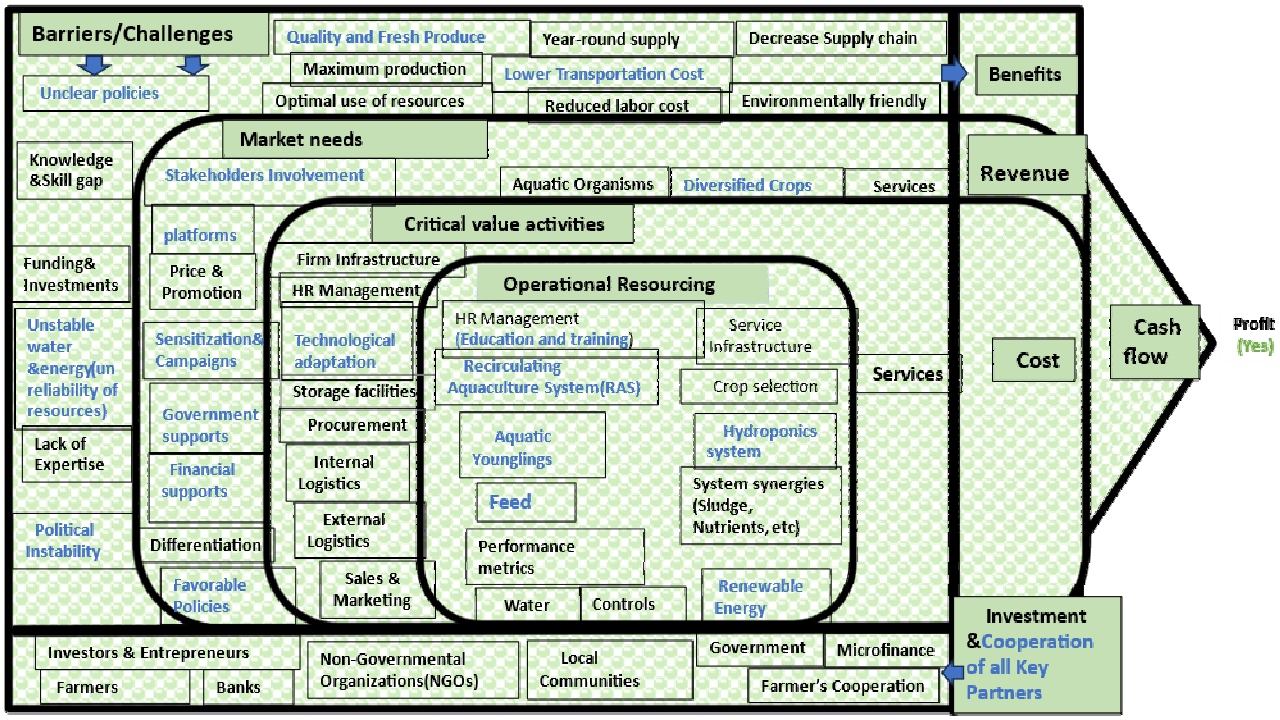

Figure 7: Vertical farming business model for Cameroon

6.2 Conclusion

The paper explores the viability of vertical farming business models in Cameroon, focusing on integrating such business models with local practices and addressing food security and sustainability. It emphasizes the need for sociocultural integration, financial support, governmental support, clear and favorable policies, and skill development for successful implementation. Despite potential benefits, challenges like infrastructural deficits and technological gaps must be overcome with stakeholder engagement, education & training, and supportive policies. This work contributes to sustainable agriculture research, offering insights for policymakers, practitioners, and researchers on adopting vertical farming in developing contexts.

7 LIMITATIONS AND SUGGESTIONS

The study faces limitations, including conducting only online interviews due to budget constraints, potentially affecting the depth of insights compared to face-to-face interactions. Technical issues with online connections impacted the clarity of transcriptions. Additionally, there was limited access to key government officials, particularly from the Ministry of Agriculture, which could have enriched the findings with more diverse perspectives and insights into regulatory and support frameworks.

To enhance the study of vertical farming business models in Cameroon, future research should include on-the-ground fieldwork for broader insights, incorporate both qualitative and quantitative methods for greater validity, delve into specific crop and fish types suitable for vertical farming business models, a delve study on the socio-cultural integration of vertical farming business that is a vertical farming culture needs to be created. A further discussion with farmers and other stakeholders to get their perspective on whether vertical farming will replace traditional practices and what role are they going to play especially the traditional farmers, also let them discuss, if they would have priority in the needed skill training of vertical farming, will they accept socially and culturally the change from rural to urban life?. Additionally, developing a financial model specific to Cameroon's context would significantly benefit local farmers and how staple crops like maize, wheat, etc… can be done using vertical farming techniques.

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Examination of Sustainable Human Resource Management on Employee Performance Indicators

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1 ABSTRACT

In recent years, the topic of sustainable human resource management (SHRM) has become increasingly important (Piwowar-Sulej, 2021). The benefits of SHRM are becoming increasingly apparent, particularly in light of the shortage of skilled workers and the demographic change as SHRM is expected to enhance commitment (Ehnert, Parsa, Roper, Wagner & Müller-Camen, 2016). Thus, retention management via SHRM is in the limelight instead of recruitment of employees. However, the integration of social, economical and environmental sustainability within human resource management (HRM) strategy is often lacking and thus an innovative aspect (Ehnert et al., 2016; Kramar, 2022; Piwowar-Sulej, 2021). Moreover, the benefits of SHRM and the impact on employee performance indicators have rarely been analyzed empirically (Peerzadah, Mufti & Nazir, 2018). Thus, this paper aims at closing this gap by answering the following research question: To what degree does SHRM increase or decrease employee performance indicators? This study contributes to the social dimension of sustainability and thus contributes to the current SHRM debate with the aim of gaining insights into the impact of SHRM practices on employee performance, which will be evaluted quantitatively in order to close the aforementioned gap. Thus, a conceptual framework based on existing literature, the transactional stress model (Lazarus & Folkman, 1984) as well as the Job Demands-Resources model by Bakker and Demerouti (2007) will be developed. The framework is used to evaluate the impact of SHRM on employee stress, employee engagement, employee turnover and affective commitment. It is anticipated that a deeper understanding will be gained regarding the relevance of SHRM in business environments.

Keywords: Employee Performance, Sustainable Human Resource Management, Stress, Sustainability, Commitment

2 INTRODUCTION

The topics sustainability and responsibility are of increasingly importance for German companies due to regulatory aspects but also due to employees asking for more sustainability (Doyé, 2016). Dealing responsibly with social, economical and ecological challenges in particular is an important component of competitiveness for companies (Doyé, 2016). In this context, employees are considered to be responsible for day-to-day business processes, as their knowledge and skills form the basis for sustainable corporate management and help to shape the corporate culture (Doyé, 2016.). The long-term retention of employees is becoming increasingly important in order for companies to successfully tackle challenges such as the shortage of skilled workers, demographic change and the decline in highly qualified employees (Kraft & Drossel, 2019).

For this reason, new human resource management (HRM) concepts have emerged in recent years, particularly with regard to sustainability (Piwowar-Sulej, 2021), like sustainable human resource management (SHRM). It is based on the original definition of sustainability, which was mentioned in the year 1713 in forestry by Carl von Carlowitz first and was subsequently shaped by the Brundtland Commission in the year 1987 in the report Our Common Future. This new HRM concept aims at ensuring employees to achieve positive financial, social, sustainable and environmental outcomes within the organization in the short and long term (Ehnert et al., 2016; Kramar, 2022; Piwowar-Sulej, 2021). According to Kramar (2022) as well as Cohen, Taylor and Müller-Camen (2012), SHRM is of paramount importance when including sustainability as a central part of HRM strategy as well as the operational implementation in businesses.

Even though SHRM has been able to generate more attention in recent years, the research stream of SHRM is still developing (Anlesinya & Susomrith, 2020). There are several knowledge gaps in the areas of

economical and social SHRM, as the primary focus – so far – is on the ecological part of SHRM. In addition, the influences of SHRM have largely been investigated from a management perspective (Anlesinya & Susomrith, 2020; Kramar, 2022). However, the perspective of employees is still lacking in SHRM research. Thus, there is a need for increased research in the field of SHRM (Anlesinya & Susomrith, 2020; Kramar, 2022; Qamaret, Afshan & Rana, 2023). According to Kramar (2022), models for the implementation of SHRM have to be expanded regarding the benefits of sustainability and to create guidelines for the operationalization of SHRM. For this reason, this paper aims at analyzing the nexus of SHRM and employee performance indicators for closing the gap by focusing on the social perspective of sustainability in order to answer the following research question: To what degree does SHRM increase or decrease employee performance indicators? Thus, this study will contribute to knowledge in the field of SHRM by (1) developing a conceptual framework on SHRM and its effects on employee performance indicators and (2) by measuring, analyzing and evaluating the anticipated effects, i.e., the impact of SHRM on employee performance indicators based on a self-developed SHRM model.

3 LITERATURE REVIEW

Clarifying the terminologies used in this paper and distinguishing between related concepts are essential for understanding the conceptual framework. In the following section, various perspectives from existing research are presented, which were analyzed during a narrative literature review. Building on this, the conceptual framework is developed, serving as the basis for answering the research question initially proposed.

3.1 Sustainable Human Resource Management

The economic efficiency and effectiveness of personnel management, traditionally regarded as success, emphasizes the efficient deployment and utilization of personnel (Ehnert, 2008; Ehnert et al., 2016). This is possible if sufficient high-quality human resources are available (Ehnert, 2008.). If this is not the case, sustainable human resource management strategies and practices must be employed additionally (Ehnert, 2008.). These include issues such as improving the work-life balance of employees, health care, regeneration of employees, or the preservation of social legitimacy (Ehnert, 2008; Ehnert et al., 2016). It expands the economic goals to include the social perspective, i.e., social responsibility (Kramar, 2022). SHRM defines its core mission as the management of people to support the United Nations (UN) Sustainable Development Goals (SDGs) and SHRM achieves comprehensive organizational goals on the social, econimical as well as ecological perspective (Cohen et al., 2012). The implementation of SHRM positively influences the UN SDGs and promises economic success (Kramar, 2022). It is beneficial for companies, has a positive impact on employees' health and reduces absenteeism (Ehnert, 2008; Ehnert et al., 2016). SHRM follows the concept of the Triple Bottom Line (TBL) – Planet, People, Profit (Elkington, 1997) – and includes environmental, social and financial dimensions, contributing to environmental quality, social justice, and the financial performance of the organization (Cohen et al. 2012). SHRM includes traditional HRM tasks as well as more modern tasks such as image building, developing environmental awareness and gaining a competitive advantage (Merlin & Chen, 2022).

3.2 Performance Indicators

To operationalize employee performance, it is important to identifiy and evaluate validated scales on the individual level. Therefore, in the current study, validated Likert scales were used to measure and analyze the impact of SHRM on employees. The selection of the performance indicators was based on the individual indicators of the Job Demands-Resources model by (Bakker & Demerouti, 2007) and includes the following employee performance indicators: stress, employee engagement, employee turnover, and affective commitment. The scales used to measure SHRM and the employee performance indicators have been developed by Felfe, Six, Schmook and Knorz (2002), Shafaei (2020), Klein, Brähler, Dreier, Reinecke, Müller, Schmutzer, Wölfling and Beutel (2016); Roodt (2004) as well as Schaufeli and Bakker (2004). Employee performance plays an important role in contributing to organizational goals. It describes a scalable action, outcome and behavior which is linked to accoplishing and meeting work-related goals as well as fulfilling expectations (Atatsi, Stoffers & Kil, 2019; Campbell & Wiernik, 2015). To conceptualize employee performance, it is important to distinguish performance into action, e.g., behavior, and outcome, e.g., result, of performance (McCloy, Campbell & Cudeck, 1994). The behavior-related aspect refers to what a person

does in a certain situation at work, whereas the outcome-aspect of performance depends on factors other than the individual's behavior but focus on the generated result(s) (Sonnentag & Frese, 2005).

3.3 Job Demands-Resources Model

The Job Demands-Resources model (JD-R) predicts work factors influencing employee well-being, motivation as well as organizational outcomes (Bakker & Demerouti, 2007). Originally developed to identify the causes of burnout, it also predicts employee engagement, job performance, conflict and organizational consequences (Lesener, Gusy & Wolter, 2019). It distinguishes between job demands and resources, with demands having a positive effect on strain, while resources have a positive effect on motivation as well as on the nexus between job demands and strain, e.g., stress and well-being (Bakker & Demerouti, 2007). Job resources are, for example, social support, autonomy and feedback, while demands are for instance on a mental, physical or emotional dimension (Bakker & Demerouti, 2007).

The JD-R model provides two main psychological relationships for work motivation and stress (Bakker & Demerouti, 2007). One relationship concerns the nexus between demands and stress, while the other considers the role of resources in improving work motivation and reducing the strength of the relationship between job demands and strain, like cynicism as well as stress (Bakker & Demerouti, 2011; van Beurden, van De Voorde & van Veldhoven, 2020). However, high levels of stress can affect organizational outcomes (Ryan & Deci, 2000; Schaper, 2014). Resources can satisfy psychological needs, such as affiliation to others or a community, the pursuit of autonomy and competence, then they possess motivating effects (Ryan & Deci, 2000; Schaper, 2014). These characteristics are present in the SHRM concept (Ehnert et al., 2016). SHRM is thus understood as a job resource as it includes employee involvement, recruiting, rewarding, training and achieving social responsibility as well as gaining a competitive advantage (Merlin & Chen, 2022).

3.4 Transactional Stress Model

The transactional stress model by Lazarus and Folkman (1984) is a cognitive model that considers the cognitive and emotional evaluation of stress situations as well as available coping mechanisms (Richter & Hacker, 1998). Lazarus emphasizes the influence of the demands of a situation on an individual's stress response (Lazarus & Alfert, 1964). In the model, a person's stress response depends on their subjective assessment of stressors, while the assessment process is divided into the primary, secondary, and reappraisal stage (Lazarus & Folkman, 1984). Depending on the individual assessment, a situation may be perceived as a threat.

Referring to (Lazarus & Folkman, 1984), the primary appraisal categorizes the situation into irrelevant, friendly/positive, or strenuous/distressing situations. In the secondary appraisal, it is examined whether existing resources and coping strategies are sufficient for handling the situation. If not, stress occurs. In the reappraisal, the person decides whether adjustments are necessary (Lazarus & Folkman, 1984). Stress occurs when a person, based on the assessment, fears being unable to meet the demands of a situation. The model is well-suited as a basis for prevention measures and provides insights into the causes of long-term stress effects (Schaper, 2014).

4 DEVELOPMENT OF A CONCEPTUAL FRAMEWORK

The study explains the relationships between SHRM and various employee performance indicators by combining existing theory, i.e., JD-R and transactional stress model, and an extensive narrative literature review. The JD-R assumes that job resources, e.g., social support, autonomy, and feedback, are associated to employee motivation that can lead to higher outcomes, while the relationship between job demands and stress declines (Ababneh, 2021; Bakker & Demerouti, 2011; Opatha, 2016; van Beurden et al., 2020). As aforementioned, these characteristics of job resources are also included in the concept of SHRM. Therefore, the findings of the JD-R can be applied to SHRM, which classifies SHRM as a job resource.

SHRM supports employee growth, learning and development, assists management and reduces absenteeism, health problems and associated company costs regarding the employees (Ehnert, 2008; Ehnert et al., 2016; Sonnentag & Frese, 2003). Hahn and Dormann (2013) reinforce that employee engagement is related to job performance and is influenced by job resources. Peerzadah et al. (2018) agree with this finding and expand upon it with the insight that SHRM leads to an improved work life and reduced turnover. The combination of

the findings suggest that employee engagement mediates the relationship between SHRM and employee turnover (Hahn & Dormann, 2013; Peerzadah et al., 2018). Furthermore, SHRM has positive effects on employee health, which can reduce the negative consequences of stress, such as increased absenteeism and health problems (Sonnentag & Frese, 2003). Thus, the following hypotheses are proposed:

H1: SHRM is negatively related to stress.

H2: SHRM is positively related to employee engagement.

H10: Employee engagement negatively mediates the relationship between SHRM and employee turnover.

According to the transactional stress model by Lazarus and Folkman (1984) the perception and management of stress situations vary individually, leading to different reactions – positive, negative, or irrelevant. This paper refers to stress in a negative way from the individual perspective which in the long-run also negatively affect organizational performance (Tirrel, Kaufmann & Winnen, 2021). The World Health Organization confirms that perceiving a situation as stressful can impair the ability to process or complete tasks (World Health Organization, 2023). Ryan and Deci (2000) state that high levels of stress can negatively impact the pursuit and achievement of goals, which reduces outcome-oriented motivation. Bakker, Demerouti and Sanz-Vergel (2014) point out that stress negatively affects employee engagement, as engagement is understood as vigor and dedication. Hahn and Dormann (2013) emphasize that reducing stress is crucial for employees' performance and well-being. Furthermore, prolonged high stress can lead to burnout (Bakker et al.,2014). The following hypothesis is thus proposed:

H3: Stress is negatively related to employee engagement.

A study by Gilboa, Shirom, Fried and Cooper (2008) uncovered that job satisfaction is negatively affected by stress. This might be the case because employees are feeling stress as a negative aspect which they probably can not control, i.e., make their own choice on how to deal with it according to the transactional stress modell (Lazarus & Folkman, 1984; Sonnentag & Frese, 2003). However, a decrease in job satisfaction can lead to increased employee turnover (Bakker & Bal, 2010; Kramar, 2022; Tirrel and Winnen, 2017). To reduce turnover rates, it is suggested to organize employee training, promote employee well-being, reduce stress, and achieve competitive advantages (Kramar, 2022). Sonnentag and Frese (2003) uncovered that stress negatively affects employee commitment and positively affects employee turnover. Bakker and Bal (2010) discovered that employees experience the highest engagement in challenging and resource-rich work environments. This can lead to increased emotional commitment of employees to the employer, known as affective commitment (Allen & Meyer, 1990). Kanning (2017) emphasizes that the likelihood of employees staying with a company increases when job satisfaction, social identification, and commitment are strongly pronounced. Therefore, the following hypotheses are derived:

H4: Stress is positively related to employee turnover.

H5: Stress is negatively related to affective commitment.

Kahn (1990) explains that engaged employees express themselves physically, cognitively, and emotionally in their work and identify strongly with it. Employee engagement is defined as a positive, work-focused psychological condition that binds employees to their workplace (Schaufeli, Salanova, González-Romá & Bakker, 2002; Takawira, Coetzee & Schreuder, 2014). Promoting resources and reducing stress are crucial for employee performance and well-being (Hahn & Dormann, 2013). Employee training and promoting well-being can reduce turnover (Kramar, 2022; Ruso, Glogovac, Filipović & Jeremić, 2021). Bakker et al. (2014) describe employee engagement as a positive motivational condition in the JD-R model. Job satisfaction and motivation are key factors for affective commitment (Westphal & Gmür, 2009), which arises when employees feel an emotional connection to their employer (Allen & Meyer, 1990). Van Dick and Ullrich (2004) expand this approach by including the great personal significance of the organization for the employee, which leads employees to be greateful to belong to it in the future as well. Higher job satisfaction, social identification, and commitment increase the likelihood that employees will stay within the company (Kanning, 2017; Westphal & Gmür, 2009). Practices to increase well-being and affective commitment can reduce employee turnover (Bowling, Khazon, Meyer & Burrus, 2015; Kanning, 2017; Kramar, 2022; Meyer, Paunonen, Gellatly & Goffin, 1989; Westphal & Gmür, 2009). Caldwell, Chatman and O'Reilly (1990) as well as Süß (2006) confirm the positive relationship between motivation and affective commitment. Allen and Meyer (1990) state that high affective commitment is associated with high engagement, high job

performance, low turnover, and high well-being. The aforementioned findings of Bakker et al. (2014), Bowling et al. (2015), Kanning (2017), Kramar (2022), Meyer et al. (1989) as well as Westphal and Gmür (2009) suggest that affective commitment has a negative mediating impact on the relationship of employee engagement towards employee turnover. Based on the findings, the following hypotheses are proposed:

H6: Employee engagement is negatively related to employee turnover.

H7: Employee engagement is positively related to affective commitment.

H9: Affective commitment negatively mediates the relationship between employee engagement and employee turnover.

According to Felfe (2008), employees are more committed to the goals and interests of the company when they feel a connection to the organization. He also states that they are more willing to accept changes and new developments while remaining loyal to the company, even when attractive job opportunities arise elsewhere. Three phenomena play a crucial role in ensuring a positive bond between employees and the company: job satisfaction, social identification, and commitment (Kanning, 2017). The stronger the job satisfaction, social identification, and commitment, the more likely it is that employees will stay with the company (Kanning, 2017; Westphal & Gmür, 2009). According to Allen and Meyer (1990), a high positive level of affective commitment is associated with low turnover, low absenteeism, and high well-being. Conversely, this suggests that a high level of stress can reduce affective commitment. These findings lead to the following hypothesis:

H8: Affective commitment is negatively related to employee turnover.

Based on the aforementioned theories and on the findings from the narrative literature review, the hypotheses were derived. This leads to the following synthesized conceptual framework (figure 1), which constitutes our first contribution to knowledge. This conceptual framework has a comparable structure to the JD-R, underlining the strong theoretical foundation.

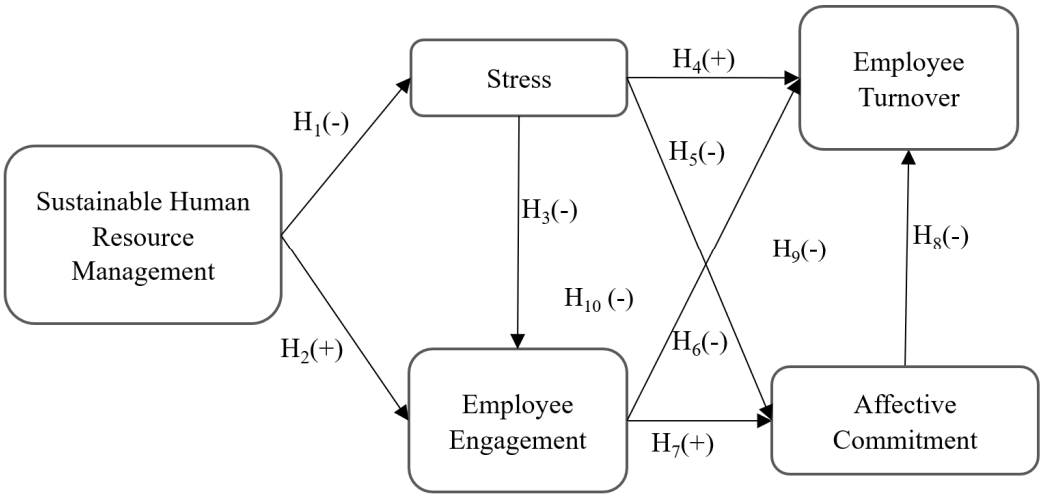

Figure 1: Conceptual Framework of SHRM on employee performance indicators, own depiction.

5 METHODOLOGY

In order to analyze the data, the usage of partial least squares structural equation modeling (PLS-SEM) is intended. This procedure has been used in several business research projects and enables researchers to make predictions (Hair, Hult, Ringle & Sarstedt, 2022; Sarstedt, 2019). Moreover, complex models including latent variables can be evaluated (Ringle, Wende & Becker, 2022), which represents the limelight of our study. Prior to data analysis, the minimum sample size will be calculated by using G*Power analysis (error probability .05; power .8) (Faul, Erdfelder, Buchner & Lang, 2009). This procedure defines a minimum sample size based on the conceptual framework. In order to achieve the minimum sample size, an online questionnaire will be distributed virtually, especially via social media, so a cluster and snowball sampling will be applied (Miles, Huberman & Saldaña, 2014; Teddlie & Tashakkori, 2009). Therefore, five-point Likert scales including a cannot answer option will be used. For analyzing the generated data, SmartPLS software version 4.0.9.8 (Ringle et al., 2022) will be used since SmartPLS is “the most comprehensive software” (Henseler, 2017, p. 373).

For generating high quality and reliable results, the analytical procedure, as recommended by Hair et al. (2022), will be followed. Thus, first the measurement model will be evaluated before second, the structural model assessment follows. This also includes the analysis of significance and relevance of the a priori developed hypotheses referring to the conceptual framework. Additionally, in order to assess the common method bias, Harman's single factor test is about to be applied (Podsakoff et al., 2003). Since generated data will be handled confidentially as well as anonymously, it is not expected to be biased (Chatterjee, Chaudhuri, Thrassou and Vrontis, 2022). However, SPSS version 29.0 will be used to evaluate whether the data is biased by using the Harman's single factor test (Chatterjee et al., 2022; Podsakoff et al., 2003). The findings of the analysis will finally be presented in April at the REAL CORP Conference 2024 in Mannheim.

6 EXPECTED RESULTS

The expected results are now listed on the basis of the developed hypotheses. The focus is on the associations between SHRM and employee performance indicators.

According to the JD-R model, job resources potentially motivate employees, enhancing employee engagement and reducing stress (Bakker & Demerouti, 2011; Van Beurden et al., 2020). SHRM, as defined above, acts as a significant job resource, contributing to employee growth, learning, and development, and reducing absenteeism and health issues among employees, which subsequently lowers organizational costs (Ehnert, 2008; Sonnentag & Frese, 2003). However, especially stress is an individual feeling which has to be decided on individually as proposed by Lazarus and Folkman (1984).

Thus, we expect SHRM to positively impact employee performance indicators in terms of lower stress (H1) and higher engangement (H2), based on the theoretical foundation of the JD-R. Moreover, it is expected that employee engagement negatively mediates the relationship between SHRM and employee turnover (H10).

In addition, stress is expected to reduce employee engagement (H3) as well as affective commitment (H5) while enhancing employee turnover (H4), referring to expected individual choices made according to the transactional stress model.

Furthermore, employee engagement is expected to be associated negatively with employee turnover (H6), again based on an individual decision made according to the transactional stress model by understanding stress in a negative manner. However, employee engagement is also expected to be positively related to affective commitment (H6), which is expected to be negatively associated with employee turnover (H8) since employees with strong emotional ties tend to stay longer with a company (Kanning, 2017).

Finally, affective commitment is expected to negatively mediate the nexus between employee engagement and turnover (H6) since a strong emotional bond might buffer the effects of engagement on turnover (Westphal & Gmür, 2009).

Therefore, after our initial conceptualization and presentation of the research design, the final results will be presented at the REAL CORP Conference in April 2024 in Mannheim. SHRM is of great importance for the society, also in smart cities, since in this case human resources are used carefully instead of overusing them which binds employees to the company in the long term. Moreover, training employees is in the limelight of SHRM. So, if for instance smart city planners are not offered the necessary trainings (Kaufmann et al., 2021), they might leave a company as they do not have the feeling of being treated fairly. This is in contrast to the company's intentions of generating sustainable human capital by their employees (Kaufmann et al., 2021). Therefore, our expected results are beneficial for companies as they are informed about the effects of SHRM on certain employee performance indicators, which are of paramount importance for HRM departments since it is getting harder to recruit employees. Thus, retention management is increasingly important, which can probably benefit from SHRM. So, companies can decide on including or excluding SHRM in strategic HRM based on empirical findings generated via analyzing the self-developed synthesized conceptual framework.

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🏆 *reviewed paper*

Exploring Community Resilience Strategies in the Face of Escalating Heat Waves: a Comprehensive Study of Giyani, South Africa

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1 ABSTRACT

The escalating frequency and severity of heat waves due to climate change pose a significant threat globally. Giyani, a rural township in South Africa, is no exception to this concerning trend, as revealed by the data collected from Meteoblue which indicates a rise in mean temperature from 22.0 °C in 2021 to 22.5 °C in 2022. Previous studies have documented the manifestation and multifaceted effects of escalating heat waves on local communities worldwide. However, what remains to be known clearly are the strategies of communities in dealing with the escalating heat waves. Consequently, this paper discusses the Giyani community's resilience mechanisms in the face of escalating heat waves in the past few decades. Employing a descriptive research design and a mixed-method approach, this study utilizes random sampling to draw 15 participants, reaching the point of saturation for data collection. The questioners conducted to collect the primary data with residents structured were both open and closed ended. Content analysis is then applied to analyze the data. The findings indicate that the mean temperature at Giyani further increased from 22.8 °C in 2022 to 23.0 °C in 2023. The health of community members, especially street vendors and individuals above 50 years old, is increasingly at risk. Moreover, the heat wave exacerbates water shortages, impacting both residents and the agricultural sector. Several mechanisms to deal with the escalating heat waves include healthcare support, urban planning and green spaces, climate- resilient agriculture and water management. Such strategies that enhance community resilience need to be facilitated and promoted to enhance sustainable practices in the face of the changing climate conditions in Giyani. Adverse effects of heat waves need to be mitigated, ultimately, this study contributes to the broader discourse on climate adaptation and community well-being in regions experiencing the intensification of heat waves.

Keywords: Planning, Giyani, Community resilience, Climate change, Heat wave

2 INTRODUCTION

The Mopani District, situated in Limpopo Province, has undergone substantial climatic shifts, marked by an alarming increase in heat episodes and a consequential decline in rainfall, rendering it increasingly unreliable (Adebanji, 2017). These transformations not only mirror the evolving face of the local climate but are indicative of broader regional climate scenarios (Hannaford and Nash, 2016). The gravity of these changes has been underscored in the Mopani District's Integrated Development Plan, where explicit acknowledgment is given to the shifting climate patterns and the attendant threats they pose. These threats, encompassing challenges to access potable water, food security, and the health impacts on impoverished communities, emphasize the urgent need for proactive measures to address the escalating climate crisis (Ullah and Akhtar, 2023).

The ramifications of this climatic challenge extend beyond the borders of the Mopani District to encompass the Greater Giyani Municipality, which falls within the district (Jimoh et al, 2021). This municipality, too, is characterized by climate sensitivity and water stress, amplifying the complexity of the issue. The manifestation of climatic changes is not confined to the district alone but resonates throughout the broader Limpopo Province, signalling potential direct impacts such as droughts, floods, and wildfires (Sithole, 2023). These environmental upheavals, in turn, give rise to ancillary consequences, affecting both health and social systems.

The health implications of these climatic changes are profound, with an increased occurrence of climate-prone diseases such as malaria, measles, typhoid fever, cholera, and diarrhoea. Poverty-stricken communities are particularly vulnerable, exacerbating existing challenges (Li et al, 2021). The interconnectedness of these

factors underscores the need for a comprehensive understanding and targeted interventions to mitigate the adverse impacts on both the environment and the well-being of communities.

This study seeks to delve into the multifaceted challenges arising from climatic changes in the Mopani District and the Greater Giyani Municipality. By examining the direct impacts on environmental stability, health, and social systems, the research aims to contribute valuable insights toward the formulation of effective strategies for climate adaptation and resilience-building in these vulnerable regions.

3 THE GROWING THREAT OF HEAT WAVES

Heat waves are becoming a looming threat to the globe. Characterized by excessively high temperatures and humidity, they are becoming increasingly frequent, intense, and prolonged. A heat wave is generally defined as a prolonged period of excessively hot weather, which may be accompanied by high humidity (Rafferty, 2024). The exact definition can vary regionally and is often based on specific temperature thresholds relative to the local climate. In meteorology, a common definition involves temperatures that exceed the historical average for a given period, typically several days to weeks (Department of Health, 2021). Heat waves can have significant impacts on human health, ecosystems, and various socio-economic sectors.

3.1 Characteristics of Heat Waves

There are certain characteristics of heat waves. These characteristics are the ones that makes a heatwave to be noticeable. Heat waves are characterized by their extended duration, typically lasting for several days to weeks (Pascal et al, 2021). The prolonged nature distinguishes them from short-term temperature spikes. In addition, there is persistence of high temperatures even during the night (Chen et al, 2020). Night-time temperatures may remain elevated, offering little relief and contributing to health-related concerns. High temperatures during a heat wave are notably more intense than usual, surpassing the normal range for the region. Intensity is often measured by comparing temperatures to historical averages. Heat waves can cover vast geographical areas, affecting multiple regions simultaneously (Horton et al, 2016). The extent of the affected area contributes to the overall severity and impact of the heat wave. Changes in the frequency of heat waves over time may be indicative of climate trends. An increase in the frequency of extreme heat events is often associated with climate change.

3.2 Impacts of Heat Waves

Heat waves can have cascading effects on ecosystems, water resources, and agriculture. Drought conditions, wildfires, and stress on plant and animal populations may be exacerbated during heat waves (Sithole, 2023). Heat waves pose substantial risks to human health. Heat-related illnesses, such as heat exhaustion and heatstroke, become more prevalent during these periods (Pascal et al, 2021). Vulnerable populations, including the elderly and those with pre-existing health conditions, are particularly at risk. The socio-economic impacts of heat waves include decreased labour productivity, increased energy demand for cooling, strain on infrastructure, and potential disruptions to daily life (Smith et al, 2021).

Understanding these characteristics is crucial for developing effective strategies to mitigate the impacts of heat waves and enhance community resilience in the face of changing climatic conditions. Climate change refers to long-term changes in temperature, precipitation, wind, and other atmospheric conditions on Earth. One of the most noticeable and concerning impacts of climate change is the increase in the frequency, intensity, and duration of heat waves. Heat waves are prolonged periods of excessively hot weather, which can have widespread and severe effects on ecosystems, human health, and various sectors (Chen et al, 2020).

3.3 Keyways in Which Climate Change Contributes to the Occurrence and Impact of Heat Waves

As global temperatures increase due to the accumulation of greenhouse gases in the atmosphere, heat waves become more frequent and severe. Climate change amplifies the likelihood of extreme heat events, setting new temperature records in many regions (Masson-Delmotte et al, 2021). Climate change alters atmospheric circulation patterns, leading to shifts in weather systems. This can result in more persistent and stagnant air masses, which contribute to the prolonged duration of heat waves (Olabi and Abdelkareem, 2022).

Higher temperatures during heat waves can pose serious health risks, especially for vulnerable populations such as the elderly, infants, and individuals with pre-existing health conditions (Sithole, 2023). Heat-related illnesses, such as heatstroke and heat exhaustion, become more common during prolonged periods of

extreme heat (Pascal et al, 2021).. Heat waves contribute to increased evaporation, drying out soils and water sources. This can lead to drought conditions and water scarcity, impacting agriculture, ecosystems, and human water supplies. Heat waves contribute to the drying of vegetation, making it more susceptible to ignition. This increases the risk of wildfires, which can have devastating effects on ecosystems, air quality, and human communities (Chen et al, 2020).

Extreme heat events can harm crops and reduce agricultural yields. Heat stress during critical growth stages can affect plant development and decrease the productivity of crops, leading to food security concerns (Smith et al, 2021). Prolonged heat waves can strain energy, transportation, and water infrastructure. Increased demand for cooling systems during hot periods can overload electrical grids, leading to power outages.

Mitigating the impacts of heat waves requires global efforts to reduce greenhouse gas emissions and adapt to the changing climate (Masson-Delmotte et al, 2021). This includes developing resilient infrastructure, implementing heat action plans, and promoting sustainable practices to minimize the human and environmental impacts of extreme heat events.

3.4 Local Factors Influencing Heat Waves in Giyani

Understanding the local factors influencing heat waves in a specific area like Giyani requires considering a combination of geographical, climatic, and environmental elements. Giyani is a town located in the Limpopo Province of South Africa. Here are some local factors that can influence heat waves in Giyani:

3.4.1 Geography and Topography

Giyani is situated in a subtropical region with relatively low elevation (Mashele, 2022). Low-lying areas may experience higher temperatures, especially during heat waves, as they are more susceptible to heat accumulation.

3.4.2 Vegetation Cover

The type and extent of vegetation in and around Giyani can impact local temperatures. Vegetation provides shade and helps cool the environment through evapotranspiration. Greater Giyani has the abundance of Mopani and Marula trees (Mashele, 2022). It is mainly grassland which is often overgrazed due to overstocking. Changes in land use and vegetation cover can influence heat wave dynamics.

3.4.3 Water Bodies

The presence of water bodies, such as oceans, rivers or lakes, can have a moderating effect on temperatures (Munyai et al, 2021). They may contribute to local cooling, and changes in their availability or temperature can influence the severity of heat waves. However, Giyani is not surrounded by any oceans. it is surrounded by perennial rivers, Letaba Dam is among them, situated 40 kilometres to the west of Giyani (Khwashaba, 2018).

3.4.4 Local Weather Patterns and Climate Zone

The interaction of local weather patterns, such as the movement of air masses, prevailing winds, and the presence of weather systems, can influence temperature extremes (Smith et al, 2021). Stagnant air masses can contribute to the persistence of high temperatures during heat waves. Giyani experiences a subtropical climate, characterized by hot summers and mild winters (Maluleke and Mokwena, 2017). The region is prone to high temperatures, which can contribute to the occurrence of heat waves.

Understanding these local factors is crucial for developing effective strategies to manage and adapt to heat waves in Giyani. Local authorities and communities can use this information to implement measures such as urban planning, water conservation, and public health initiatives to mitigate the impacts of extreme heat events. Additionally, raising awareness about climate change and its local implications can foster community resilience.

4 EXISTING POLICIES AND STRATEGIES IN SOUTH AFRICA THAT ADDRESS THE IMPACTS OF HEAT WAVES AND CLIMATE CHANGE

South Africa has implemented various policies and strategies to address the impacts of heat waves and climate change. some aspects of existing policies and strategies in South Africa related to heat waves are outlined below.

Name of Policy	Description
National Climate Change Response Policy (NCCRP):	The NCCRP is a comprehensive policy framework that outlines South Africa's approach to addressing climate change, including adaptation and mitigation strategies. It recognizes the importance of addressing extreme weather events, including heat waves, and emphasizes the need for resilience in various sectors.
National Adaptation Strategy (NAS):	The NAS provides a roadmap for adapting to the impacts of climate change in South Africa. It includes measures to enhance resilience in sectors such as agriculture, water resources, health, and human settlements. Specific actions may be outlined to address heat waves and extreme heat events within the broader context of climate adaptation.
Disaster Management Framework:	South Africa has a National Disaster Management Framework that includes guidelines for managing and responding to disasters, including those triggered by extreme weather events such as heat waves. This framework may involve coordination among various government departments, local authorities, and other stakeholders in responding to and mitigating the impacts of heat waves.
Health Sector Strategies:	The Department of Health in South Africa may have specific strategies addressing the health impacts of extreme heat events. This could include public health campaigns, early warning systems, and measures to protect vulnerable populations.
Water Resource Management:	Given the importance of water resources in mitigating heat stress, South Africa likely has strategies for sustainable water resource management to ensure water availability during periods of high temperature.
Urban Planning and Infrastructure Development:	Urban planning and infrastructure development policies may incorporate measures to reduce the urban heat island effect, enhance green spaces, and promote sustainable building practices to mitigate the impacts of heat waves in urban areas.

Table 1: South African policies and strategies addressing heat waves and climate change impacts (Source: Authors 2024)

A potential gap might exist in the effective implementation and enforcement of existing policies. Ensuring that strategies are translated into concrete actions on the ground is crucial. Furthermore, there may be gaps in public awareness and education about the risks and impacts of heat waves. Strengthening public awareness campaigns can enhance community resilience. Ongoing research and the collection of local data on heat wave patterns, vulnerabilities, and impacts are essential for refining strategies. There might be gaps in the availability of up-to-date and comprehensive data.

5 METHODOLOGY

This research employed a descriptive research design. Qualitative data collection methods were utilized, aligning with Creswell's (2014) definition of qualitative research as a method for understanding complex social and psychological phenomena. The study focused on the population of Giyani. A non-probability sampling strategy was adopted, acknowledging that participants were not selected with equal chance. Specifically, random sampling was employed to recruit 15 participants. Both primary and secondary data sources were utilized. Primary data was collected through structured questionnaires containing open-ended and closed-ended questions. Secondary data comprised relevant academic journals, books, statistics, policies, and articles to supplement the primary data collection (Creswell, 2014). This multifaceted approach to data collection strengthens the research by drawing on various sources of information. Qualitative data analysis, specifically content analysis, was employed to analyse the collected data.

6 RESULTS FOR COMMUNITY PERCEPTIONS AND VULNERABILITIES

The study undertaken by the authors aimed to comprehensively examine the diverse challenges emanating from climatic changes within the Greater Giyani Municipality in Mopani District. The ensuing results encapsulate both the demographic composition of the respondents and the psychographic profiles specific to the Giyani region. The primary data encompasses the age, highest level of education, employment status and salary range. Furthermore, it encompasses the correlation between heat temperature and relative humidity in Giyani, coupled with an assessment of respondents' awareness of heat waves. Furthermore, the study explores into the economic and health adversities induced by heat waves, along with an exploration of the respondents' capacity to afford cooling systems during such climatic events.

6.1 Demographics of respondents

The participants were inquired about their demographic details, including age, highest educational level, employment status, and salary range. Age inquiries aimed to determine if respondents fell within the specified age range of 18 to 65 and to identify vulnerable age groups. Information on the highest level of education helped assess which groups might possess knowledge about heat waves. Employment status and salary range data were gathered to discern groups that could potentially afford cooling systems and those who might face financial constraints in acquiring them.

6.1.1 Age of Respondents

Age is one of the demographic profiles of the respondents. However, this criterion of the study excluded respondents below 18 and above 64 since this age group was an at-risk group. There was a total of 15 respondents from Giyani who participated in the questionnaires.

Age	Number of Respondents
18 - 20	3
21 - 30	5
31 - 40	1
41 - 50	4
51 to 64	2

Table 2: Age of respondents in Giyani (Source: Authors 2024)

As far as age is concerned, the study conducted in Giyani disclosed that most respondents were between the ages of 21–30. Out of 15 respondents, 20% were between the ages of 18 – 20. A total of 33% of respondents were between the ages of 21- 30. Furthermore, respondents between the ages of 31- 40 account for 7% of the surveyed sample. In addition, respondents between the ages of 41- 50 accounted for 27% of the total surveyed sample. A total of 13% of the respondents were aged 51- 64.

6.1.2 Level of Education

Respondents were asked to indicate their highest level of education, and 15 respondents attempted this question.

Level of Education	Number of Respondents
Primary	6
Secondary	4
Bachelor's Degree	3
Master's Degree	2

Table 3:Level of education of respondents in Giyani (Source: Authors 2024)

Out of these, 40% indicated that the primary level was the highest education acquired. Furthermore, 27% indicated that the highest acquired education was secondary level while 20% acquired a bachelor's degree. In addition, 13% of the surveyed sample indicated that a Masters degree was their highest educational achievement.

6.1.3 Employment status of participants

The figure below provides a visual representation of the occupation status of the respondents, with 15 participants responding to this particular question. The inquiry into employment status was made because of the observed correlation between employment status and income levels. Typically, individuals who are employed tend to possess higher financial resources, which can impact their ability to afford air conditioners and other cooling devices.

Figure 1: Employment status of respondents in Giyani (Source: Authors 2024)

The analysis revealed that 47% were employed, 13% were trainees, 27% were self-employed, and 13% were unemployed. Employment status significantly impacts the ability to afford cooling systems like air conditioners and fans, though income level and personal responsibilities within each category likely further influence affordability. Notably, unemployed respondents face heightened challenges in acquiring such systems.

6.1.4 Household income

One of the demographic criteria included was household income, and an attempt was made to examine the income level of respondents. Data on salary ranges were collected to identify segments of the sample that could potentially afford cooling systems and those who might encounter financial challenges in acquiring them.

Income Level	Number of Respondents
Less Than R5000	6
R5000 – R15 000	6
R15 000 – R25 000	2
R25 000 – R35 000	1

Table 4: Income Level of respondents in Giyani (Source: Authors 2024)

Out of 15 required respondents, only 10 attempted the question. Of the respondents, 5 were not comfortable disclosing their salary range and hence were excluded. Out of the 10 respondents, 60 % earned less than R5000, another 60% earned between R5000 to R15000, and 20% earned between R15000 to R25000. Furthermore, 10% of the respondents earned between R25000 to R35000.

6.2 Psychographic Profile

6.2.1 Heat wave awareness: Have you heard of heat waves?

Respondents from Giyani were asked if they ever heard of heat waves Out of the 15 respondents, 67% indicated that they are aware of the term “heat waves” while 33% indicated that they are not aware of it. As indicated from figure 2 that 4 respondents have primary level of education, 3 respondents have secondary level, 2 respondents have a bachelor's degree, and 1 respondent has a master’s degree. It might be possible that individuals with higher education levels are more likely to be aware of heat waves due to their exposure to information, either through formal education or other sources. There seems to be a correlation between education levels and awareness of heat waves. Respondents with higher education levels (bachelor's and

master's degrees) make up 30% of the sample, and it's possible that they are more likely to be aware due to their exposure to information. The data suggests that there might be a link between higher education levels and awareness of heat waves.

6.2.2 Heat Temperature vs Relative Humidity in Giyani

The graph shows the average monthly temperature and relative humidity in Giyani, South Africa, over the course of a year, from January 1, 2023, to December 31, 2023. The x-axis of the graph shows the months of the year, and the y-axis on the left shows the temperature in degrees Celsius (°C). The y-axis on the right shows the relative humidity as a percentage (%).

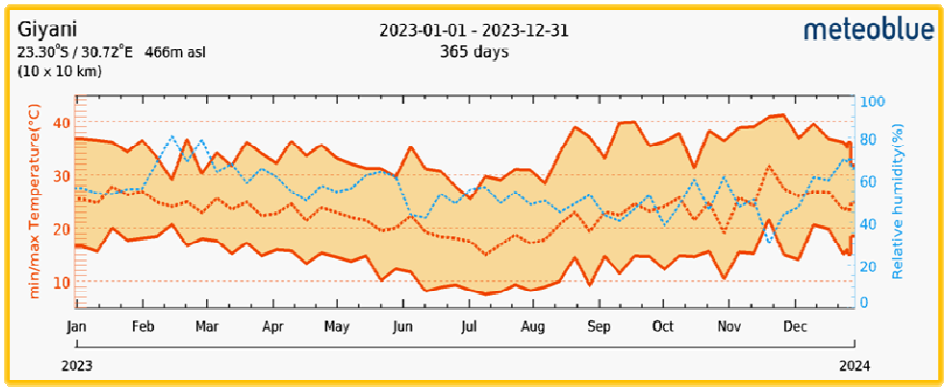

Figure 2: average monthly temperature and relative humidity in Giyani (Source: Meteoblue 2024)

According to the above 2 figure, between September and October, the temperature in Giyani went as high as 40 °C. Furthermore, the heat temperature between November and December was about 41°C.The relative humidity is generally higher in the warmer months and lower in the cooler months. However, there is some variation in this pattern, with the relative humidity being relatively high in May and June despite these months being relatively cool.

The driest months of the year are July and August, with an average relative humidity of around 40%. The wettest months of the year are December to February, with an average relative humidity of around 70%.

The figure below shows an estimate of the mean annual temperature for the larger region of Giyani. The dashed blue line is the linear climate change trend.

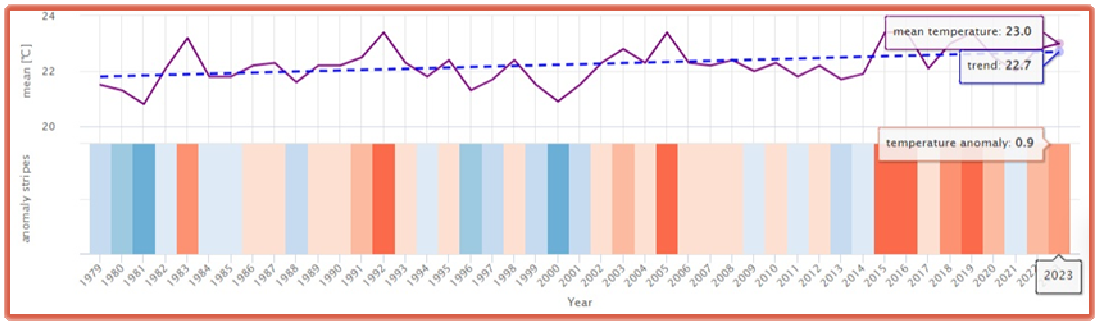

Figure 3: The mean annual temperature in Giyani from 1979 - 2023 (Source: Meteoblue 2024)

The trend line is going up from left to right; therefore, this indicates that the temperature trend is positive and that it is getting warmer in Giyani due to climate change. This is made visible by the increase in the mean temperature. In 2022, the recorded mean temperature was 22.8 °C, which increased to 23.0 °C in 2023. The lower part of the graph illustrates the warming stripes. Each coloured stripe represents the average temperature for a year. The blue colour represents colder years, and red represents warmer years. In 2022, the red colour was lighter as compared to the year 2023, which was becoming darker. This also indicated that it was becoming warmer in Giyani.

6.2.3 Impacts of heat waves: Economic and health negative impacts experienced from heat waves.

Respondents from Giyani were further asked an open-ended question if they have personally experienced health and economic impacts from heat waves. Out of the 15 respondents, 40% indicated that they have

experienced economic impacts from heat waves. They further indicated that due to the excessive heat they experience a decline in productivity and work hours. The remaining 60% percent indicated that heat wave affects their health. This 60% percent has an average age group between 31 to 64. It was highlighted that the extreme heat leads to worker fatigue, heat stress, and even heatstroke. It was also indicated that the heat waves cause the increasing risk of waterborne diseases like diarrhoea and some respondents have difficulty managing heat due to age-related health conditions.

6.2.4 Affordability to cooling systems during heat waves.

Out of the 10 respondents, 60 % earned less than R5000, another 60% earned between R5000 to R15000, and 20% earned between R15000 to R25000. Furthermore, 10% of the respondents earned between R25000 to R35000 (see figure 4). Lower income levels earning less than R5000 faced challenges in affording cooling systems during heat waves. Those earning between R5000 to R15000 also found it to be challenging to allocate resources for cooling systems, although to a lesser extent than the lower income group. Respondents earning between R15000 to R35000 had more financial flexibility, however, individual circumstances and priorities can vary. The data suggests that a significant portion of respondents (50%) may have limited financial capacity to afford cooling systems during heat waves. It is important to consider that affordability is not the only factor influencing the use of cooling systems; awareness, perceived need, and priorities also play a role.

7 CONCLUSION

The study highlights the vulnerability of the Giyani community to escalating heat waves, particularly for low-income residents and those with limited access to cooling resources and healthcare. The majority of respondents were aged 21-30, with varying levels of education and employment. Income levels ranged from below R5000 to R35000. While 67% of respondents were aware of heat waves, a significant portion lacked knowledge about the associated risks and impacts. Giyani experiences high temperatures, particularly between September and December, with relative humidity also increasing during these warmer months. Data indicates a rising mean annual temperature over the past few years. Heat waves negatively affect the community's health and economic well-being. Respondents reported experiencing decreased productivity, worker fatigue, heat stress, and increased risk of waterborne diseases. Lower income groups face significant challenges in affording cooling systems like air conditioners and fans during heat waves. The findings emphasize the need for:

- Community resilience: Building resilience can help individuals and families stay cool and healthy during heat waves. By enhancing resilience, communities can minimize these economic disruptions and ensure a more stable livelihood. Furthermore, it lays the groundwork for a future where Giyani can thrive despite these challenges.
- Community engagement and education: Communities can advocate for long-term policy changes that address systemic issues like affordable housing, access to cooling technologies, and equitable distribution of resources, contributing to broader heat resilience measures. Communities can develop heat mitigation strategies like planting trees, creating shade structures, promoting energy-efficient buildings, and advocating for urban green spaces.
- Targeted interventions: Addressing the specific needs of vulnerable populations through social support systems and affordable cooling solutions.
- Collaboration: Fostering collaboration between communities, policymakers, and stakeholders to develop effective heat wave action plans

Conducting further research, including qualitative interviews or surveys, can provide deeper insights into the specific challenges faced by different income groups in affording cooling systems.

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Exploring ESG Practises and Livelihoods Promotion Nexus in Mining Host Communities: Lessons from Aggeneys, Pella and Pofadder Mining Host Communities

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1 ABSTRACT

Investing in corporate social responsibility (CSR) has largely been dubbed/dismissed as ploys to enrich/protect the interests of investors than efforts to serve the communities. Research has shown that factors such as stakeholder collaboration contribute to Corporate Social Responsibility project implementation failure. Although the advent of Environmental, Social Governance (ESG) promises to strengthen the implementation of CSR in communities, its impact on livelihood promotion is yet to be documented convincingly. Consequently. This paper investigates influence and possible impact of Environmental Social Governance efforts in promoting the public wellbeing of the Aggeneys, Pella and Pofadder mining host communities. It explores successes and failures of Corporate Social Responsibility implementation as well as key learnings.

The Environmental Social governance philosophy promotes stakeholder engagement and involvement to promote transparency of all stakeholders and detailing individual roles and responsibility for all stakeholders. A case study research design method was adopted, and a mixed-method research approach was applied. Qualitative data was collected through interviews of mine high ranking officials and quantitative data was collected through the distribution of questionnaires to the residents of Aggeneys, Pella and Pofadder mining host communities. The results of the study presented that the deployment of a Environmental Social Governance framework has led to a sustainable livelihoods through the corporate social responsibility implementation projects such as small scale farming and broad-based livelihood programs. The paper recommends adoption of Environmental Social Governance practices to elevate and promote satisfaction of the Aggeneys, Pella and Pofadder communities. In conclusion, the knowledge contribution of this study is its focus on implementation frameworks, policies, and legislation to determine how best Corporate Social Responsibility can be implemented efficiently to unlock ultimate beneficiation for the communities.

Keywords: Socio-economic, Corporate Social Responsibility, Environmental Social Governance, Policy, Livelihoods

2 INTRODUCTION

Over the past decades with a focus on developed countries, the nexus of Environmental, Social Governance (ESG) has been used as a tool for good corperate governance practices leading to large corporations investing in this paradigm, (Taplin,2021). Mineral, oil and gas companies across both developed and developing countries have developed the nexus and is seen on their commitment to Social responsibility and development to livelihoods, (Lock and Seele,2016; Wang and Sarkis, 2017). However, Communities are still socially and spatially segregated based on their financial slopes and this has a direct impact their quality of life (Verma & Raghubanshi,2018).The study noted the gap of the lack of emperical data research in an african context towards improving livelihoods through ESG practices.

3 CONTEXTUAL FRAMEWORK

3.1 Sustainable development

The concept on Environmental Social Governance stems from the sustainable development with the aim of moving away from viewing sustainability from solely the environment but should also consider the economy and society, (Sachs,1993;Reboratti, 1999). Sustainable development can be viewed in two dimensions to bring forth the drive behind this notion. One, notes that the condition that exists today should not decline; this should be sustained for the future generations the utility should be non-declining. The latter, puts emphasis on the physical flow of nature's sources through economy and back to its natural state. This refers

to an intergenerational integrated model of development, taking into consideration the environment, social performance and the economy, (Cecchin, et al. 2021; Mathane,2023;Daly,2006).

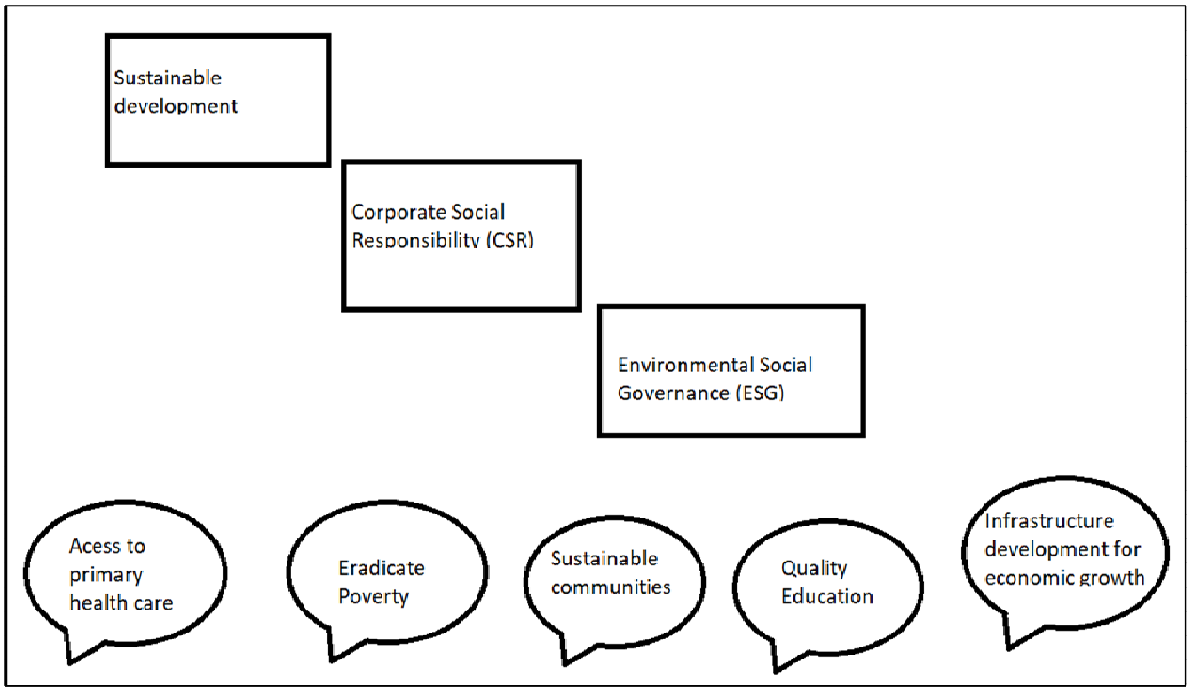

Fig. 1: Conceptual framework of the study: Source: Author (2024).

3.2 Ethical Paradox

This brings abot the concept of ethical paradox,an ecosystem should encompass the ability to sustain itself overtime even when there has been alteration to its natural state, Jabareen (2006). ESG practices promote development and this involves environmental modification interfering with ecosystems and posing a risk of natural resources exhaustion (Baeten, 2000). However, Haughton (1999) contends that the social element is of critical importance as the society is unjust as are likely to contribute negatively to the environment and or the economy, Jabareen (2006). This advocates for the concept of equity,social equity as well and the freedom to exercise equal rights for development and the improvement in quality of life, and democracy for all, this brings the world into equilibrium aiding that we achieve the notion of sustainable development (Agyeman, Bullard and Evans (2002). Therefore the ESG practices can achieve the concept of utopianism, a flawless society, where justice of the peace predominates, equity exists and there is an abundance in quality of life, without and hassles, which exudes an important aspect of positivity, Marius de Geus (1999).

3.3 Corporate Social Responsibility

“Corporate Social Responsibility” (CSR) refers to how organizations contribute to sustainability and sustainable development through their operations by achieving economic, social, and environmental sustainability (Mancini and Sala,2018). The notion of CSR follows the guidance of ISO 26000:2010 standards. It guides business practices in alignment to ethics with emphasis on social development and Governance (Rabello et al 2018) The concept of the social license to operate is directly aligned with the CSR and this speaks to the relationships which exist between organizations and their stakeholders at large (Moffat et al, 2016)

4 METHODOLOGY

This research investigated environmental, social and governance practices towards promoting livelihoods in the Aggeneys, Pella and Pofadder mining host communities in the Northern Cape province of South Africa. To collect emperical data, the study deployed an online survey to 150 participants across the Aggeneys,Pella and Pofadder mining host communities. 46.4% of the participants were from aggeneys, 29.3 % was made up of participants from Pofadder, 18.6% of participants were from Pella and 6.4% from other labour sending communities. The participants of the study were between the ages of 19 and 60. 57,8 % of the participants

ranged between ages 26-35, 19.3% between 18 and 25 years of age, 14,3 % between 36 and 45 years and 8.6 % were between 46-55.

5 FINDINGS

In the quest to explore ESG practices and their promotion on livelihoods, the study deployed a multifacited approach. The participants of the study had various inouts regading what indicates the promotion of livelihoods.. Overall, 70.7% of the study participants indicated that clean water and sanitation is significant to improving their livelihoods, whereas 60.6 % believe acess to adequate healthcare facilities is promotes livelihoods in mining host communities. This is followed by no poverty and zero hunger at 50% and thereafter decent and economic growth at 47.7%. Only 15.7% of the participants regarded affordable and clean energy as an indicator to improved livelihoods and atleast 12.1% consider innovation and infrastructure.

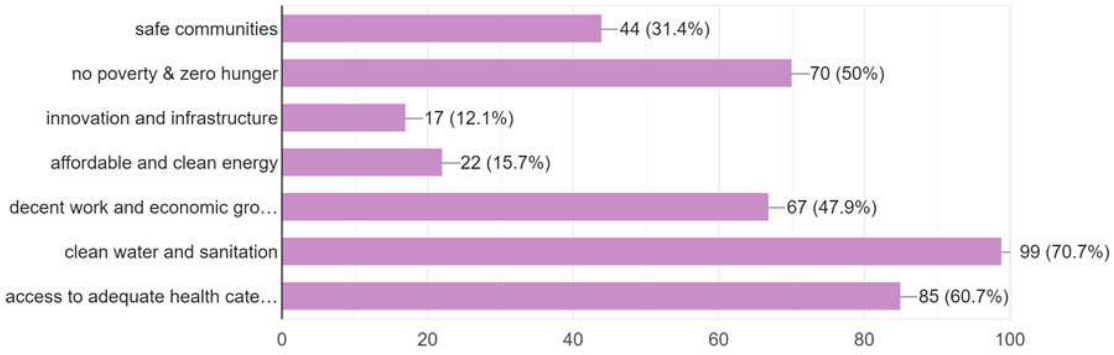

Fig. 2: Improved livelihoods indicators, (Source: Author (2024).

The emperical data collected for the study shows that 36.4 % of the participants feel that they always have acess to adequate healthcare services and facilities, 35.7 % of the participants feel that sometimes they do have acesss to adequate healthcare. An approximate 27.1% of the participants felt that they almost never have acess to adequate health care services with 0,8% feeling that they never have acess to adequate healthcare services.

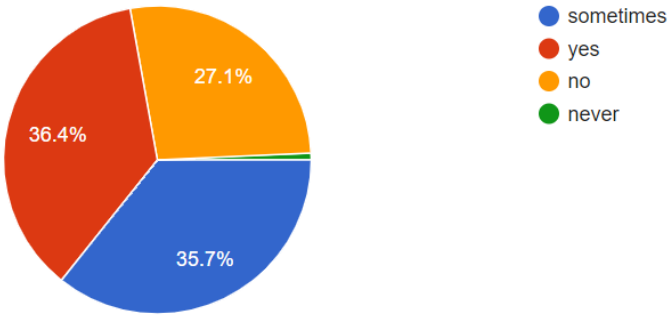

Fig. 3: Access to adequate healthcare services.

The development of the Environmental Social Governance framework has been a pioneering strength in the Aggeneys, Pella and Pofadder mining host communities as this has enabled ESG practices in the region. Furthermore, the frammeweork has strengthened collaboration amongst the host communities, the organization in operation and the local Khai-ma municiplaity. This has led to succesful corporate social responsibility projects development such as the development of the Namakwa special economic zone.

However, the results of the study show that the framework is in its early stages and there seem to be lack of participation from the local host communities which yields a threat of unsatisfaction from the local host communities and buy in is needed. Nevertheless, growth is opportune as there is opportunities for economic growth as well as attraction of invesments and ultimately improved livelihoods.

6 CONCLUSION

The study concludes that Environmental Social Governance practices are promoting livelihoods in the Aggeneys, Pella and Pofadder communities and Corporate Social Responsibility implementation is a great implementation tool for the Environmental Social Governance framework.. Majority of the respondendts agree that Clean water and sanitation, acess to adequate healthcare and no poverty are top priority in promoting great livelihoods. Although a significant quantity of participants have made it known to the researcher that they sometimes do not have acess to adequate healthcare facilities, ESG practices are bridging the gap through the development of an oncology ward in the local springbok hospital and the upgrade of the Aggeneys medical center. This illustrates the dedication of promoting livihoods and other opportunities such as economic growth and the attraction of investors inro the Aggeneys,Pella and Pofadder region. The author recognizes opportunity for improvement on the lack of participation from local host communities, the author recommends mobilization of the Environmental Social Governance framework through educational outreaches.

Strengths Development of ESG framework which anables ESG Practices Collaboration between private corporations, local government, and communities Corporate Social Responsibility project implementation Development of the Special economic zone. Medical center upgrade in Aggeneys Oncology ward in local Springbok hospital	**Weaknesses** Early statges of the ESG framework therefor gaps in implementation. Lack of participation from local mining host communities
Opportunities Economic growth through the the Special economic zone Mobilization of local host communities to make project implementation effective. Investment attraction. Improved livelihoods	**Threats** Local host communities' satisfaction. Buy in from personnel and local host communities

Table 1: Strengths, weaknesses,opportunities and threats of Environmental social governance practices in Aggeneys, Pella and Pofadder.

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Exploring Generative AI in Planning: A Scenario-Building Simulation for the Master Plan of Bari, Italy

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1 ABSTRACT

When dealing urban and regional planning, communities seek methodological approaches to deliver effective development strategies. Building up future scenarios is nowadays understood as an approach that involves expert and non-expert agents towards the organization of alternative future strategies. The so-called future-workshop approach has been followed in much research and experimentation in the past, both in real communities and in simulated situations. The present research will develop further experimentation to explore some perspectives of involving artificial intelligence agents. For this purpose, a search engine equipped with OpenAI's ChatGPT will be used to simulate future scenarios for the master plan of Bari, Italy. The involvement of generative AI will basically take place following the model of a structured interview with different stakeholders. They will be simulated by artificial intelligence to define a multi-agent knowledge base towards the construction of future scenarios for the Bari master plan.

Keywords: generative AI, simulation, scenario building, spatial planning, decision support

2 INTRODUCTION

Public managers in decision-making and planning activities are increasingly attracted by information technology for supporting decisions. The rationale for this aspiration arises from the need to ensure manageability and timeliness of policies, which are challenged and put under pressure by the prevailing complexity of managed contexts. This hard dream, however, is challenged on the one hand by a (questionable) fear of decreased personal discretionary power, and on the other by the (legitimate) fears of facing unforeseen and/or unchangeable developments (Gomes et al. 2016). However, this is a frequent decision context, showing the need for support for decision makers in managing situational and dynamic complexities. And in this context, potential for the application of intelligent knowledge management models emerges (Barbanente et al. 2007, Goodchild 2011, Borri and Camarda 2013, Calafiore et al. 2017, Couclelis 2019). Then extending over a longer perspective, with more binding dimensions and relationships between behaviours, places and territorial spaces, the role of knowledge becomes critical. The relationship between the long-term perspectives, typical of spatial planning with its basic diffused multiagent knowledge, induces the need for extremely more complex and responsible decision support models. Systems based on formalized algorithmic automatisms have often received a cautious if not skeptical reception in strategic planning contexts, often judging the basic black-box essence frequently present in them to be unbearable and unrealistic (Castelvecchi 2016, Carabantes 2020, Malekpour et al. 2020). Instead, models based on the so-called future scenario-building (SB), an iterative and interactive evolution of the strategic planning models launched in the UK in the 1970s, have reported greater success over time (Friend and Jessop 1969, Jungk and Mullert 1996, Rickards et al. 2014, Santoro et al. 2020). It is a process in which the collection and exchange of knowledge play a central role. In a SB process there are stages involving agents with expert knowledge as well as community agents with common knowledge. In this context, artificial intelligence could play an important role as a support for managing complex knowledge, elicited and made available in terms of formalized or formalizable databases. This manageable evolutionary knowledge base could in principle form the basis of decision support for long-term spatial planning tasks.

Indeed, SB models have already historically been oriented towards representing this knowledge support for strategic planning (Myers and Kitsuse 2000). The stages of interaction with expert agents as well as with common-sense (non-expert) agents represented the operationally robust and effective turning point of processes originally governed by only top-down deliberations. Experiences in this sense are activities carried out in many European and North American contexts starting from the so-called futures studies in the 1990s (Sardar and Ravetz 1996, Bell 2003). Attempts to intelligently manage these processes have been increasingly carried out in recent years, following the progressive spread of internet-based interaction

methods, involving knowledge agents located variously across the planet. Subsequent experiments have taken place in this domain, aimed at formulating and managing informal and often qualitative data formalizations, in order to feed real-time decision support architectures (Camarda 2008, Vervoort et al. 2010, Santoro, et al. 2020). The orientation of these attempts was to draw on hybrid mathematical modeling, inspired by data-mining, machine-learning and in some way supervised to minimize the black-box effect as much as possible (Sullivan 2022, Wang and Biljecki 2022). In this context, the recent availability of generative AI platforms on search engines traditionally used for searching over the internet has shown up. This circumstance therefore represented the opportunity to investigate the potential of integrating SB-based planning processes with GPT-based environments (Camarda and Patano 2023).

In this framework, the present work aims to explore suggestions of applicability of generative artificial intelligence models for the construction of future scenarios oriented to spatial planning. Therefore, after this introduction, the paper presents and comments on experiments developed in the context of scenario-building modeling in chapter 2. The work ends with a final chapter discussing the results and follow up.

3 MATERIALS AND METHODS

3.1 Studying futures: Experiences and reflections

Spatial planning is an area that intrinsically incorporates the future dimension, pre-figuring it out and then attempting to implement it. The future scenarios approach in planning was developed within the so-called Futures Studies (Bell 2003). It is based on the principle that the future is not unique, but rather requires consideration of multiple potential lines of development. Futures studies embraces uncertainty as an integral part of reality and focuses on how to address the future proactively. Futurists explore, invent, propose, analyze and evaluate possible, probable or desirable scenarios. They see the future as shaped by current choices and actions, with impacts and consequences to be carefully examined (Sardar and Ravetz 1996).

Many attempts have been made to try to structure the diffused qualitative knowledge coming from this approach and make it usable to support informed decisions. Qualitative-quantitative structuring approaches of diffused knowledge have had wider application. In particular, the future-workshop approach has achieved some success, due to its ability to consider individual and collective, critical and proactive contributions, generating possible strategic paths for the creation of alternative scenarios (Khakee et al. 2002, Iwaniec et al. 2020).

Future Workshops		
PHASE	**CONTENTS**	**EXPECTED RESULTS**
1. Preparation	The issue to be analysed is decided and the structure and environment of sessions are prepared.	Summary of contributions.
2. Critique	Clarification of the issue selected, of dissatisfactions and negative experiences in the present situation.	Problematic areas for the following discussion definition.
3. Fantasy	Free idea generation (as an answer to the problems) and of desires, dreams, fantasies, opinions concerning the future. The participants are asked to forget the practical limitations and the obstacles of their present reality.	Indication of a collection of ideas and choice of some solutions and planning guide lines..
4. Implementation	Going back to the present reality, to its power structures and to its real limits, to analyse the actual feasibility of the previous phase solutions and ideas. Identification of obstacles and limits to the plan implementation and definition of possible ways to overcome them.	Creation of strategic lines to be followed in order to fulfil the traced goals. Action plan and implementation proposal drawing.

Figure 1 – The future-workshop approach to scenario building process (Khakee, et al. 2002)

With this approach, many implementation and experimental activities of participatory strategic planning have been developed until recently. To limit ourselves to activities developed by our working group, we can

mention and briefly comment on some of them, with the aim of introducing the rationale that led to the exploratory experimentation proposed subsequently.

3.2 Some case studies of participatory scenario building

At the beginning of year 2000 our research group was involved in a European project with Mediterranean countries concerning sustainable planning processes for land and water uses. The first step of the project involved Tunisia (Khakee, et al. 2002). An essential part of the Tunisian case was the participatory construction of future scenarios regarding the area of the capital Tunis. The process involved 22 participants, mainly from institutional and research bodies, for approximately a week of overall work. The result was the definition of three alternative scenarios, named by the group with synthetic labels, of which the first is reported as an example case (figure 2).

ECO CITY

VISION	PROBLEMS	STRATEGY
Healthy and sustainable environment	cost degree of public involvement economic means brake in economic development waste generation	integration of landscape projects in economic development plans fight against anarchical urbanisation waste management
Bio-agriculture integrated into the urban environment	low yield land fragmentation blocking of public projects (schools, hospitals, networks) water scarcity (irrigation)	research on bio-agricultural techniques diffusion of bio-techniques to farmers and consumers
Transparent land market	market failures insufficient supply wild competition between different economic operators	tax system proper organisation of land agencies market incentives
Diversity of cultural and historical resources	high maintenance costs lack of craftsmen rapid and anarchical urbanisation	upgrading of cultural resources reconciling past, present and future making development resources more accessible promotion of urban sustainable environment

Figure 2 – The Eco-city scenario built in Tunis (Khakee, et al. 2002)

The Tunis process was able to involve not many common knowledge and non-expert agents, but mainly institutional expert agents. This is because access to these forms of participatory democracy were practically absent at the time there, and it was very difficult to involve communities and citizens. Of course, this ended up determining a prevalence of themes detached from the individual contexts of normal life and oriented towards general themes. However, the process was developed with assiduity and diligence by the participants, allowing all the planned stages to be completed - a rather rare case in relation to the long times usually needed (Puglisi 2001).

With the aim of broadening participation to groups of common knowledge, involving stakeholders located in different places and in asynchronous times, in 2003 the scenario building process was developed for the Rabat/Casablanca area, in Morocco (Barbanente, et al. 2007). The process in this case took place in two parallel sessions, with and without the use of the PC, to verify the potential and limits of the two different contexts. In total there were 30 participants, divided equally into the two sessions. Subsequently, a remote experimental session was carried out which aimed to refine the results already obtained in the original process. However, this final experimentation, which suffered from many problems such as time, unreliability and connection costs which were widespread at the time, was not ultimately integrated into the structure of

the results. Also in this case, three alternative scenarios were generated, named by the group with synthetic labels, the third of which is reported as an example case (figure 3).

R/C as an agricultural and ecological centre in the Maghreb

Infrastructure and territorial development

All major rural centres are connected to major towns and cities in the region in order to facilitate marketing of rural products. Infrastructure development has put a major emphasis on agricultural development. Improved transportation and storage facilities have considerably raised the marketing of food products.

Economy

Trade hinders within the Maghreb have been removed in order to allow a more diversified and competitive agriculture. Agricultural differentiation within the region and other regions of the Maghreb has been implemented which has resulted in the establishment of many small-scale industries to meet the needs of rural population. Eco-tourism is a flourishing part of the regional economy.

Cultural and social development

Education resources have been successfully used to reduce illiteracy. Partial privatization of health and social security systems has led to benefits for population in urban as well as rural areas of the region. Intra-regional economic differences have been reduced which has led to a dramatic curtailment of neighbourhood antagonism and criminality.

Strong competitiveness has made IT available in rural areas.

Politics

Local autonomy characterises public management. Increased reliance on civil society in public decision-making has paved the way for the attainment of the objectives of sustainable development.

Figure 3 – The agricultural/ecological scenario built in Rabat/Casablanca (Barbanente, et al. 2007)

Even the Rabat process was able to involve a few common knowledge, non-expert agents. However, the PC-based session also involved university students, mainly due to the limited digital knowledge among institutional officials at that time. However, the lack of diffusion of forms of participatory democracy was also present in Rabat, making it still difficult to involve communities and citizens. In the case of Rabat, alongside the prevalence of statements oriented towards general themes, interests arose in terms of implementation which were only sketchy in Tunis. It should be noted that all three scenarios were generated with rich and argued texts, permitted by verbatim ex-post consultation of the minutes, available in detail on the digital chat registers. This confirmed an effective role of PC-based support in guaranteeing a more substantially articulated and rapidly consultable knowledge base (Vervoort, et al. 2010).

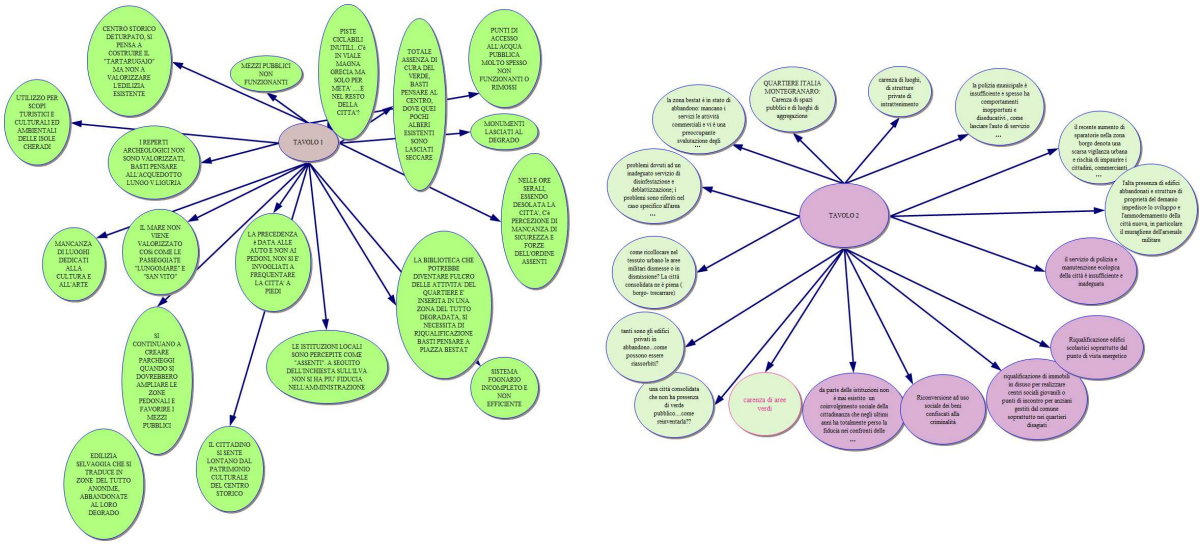

Figure 4 – Concept maps of problems in Taranto process - original Italian excerpts (Camarda 2018)

Many further operational and experimental activities for the application of scenario building processes were carried out by our group in the following period (Borri et al. 2008, Camarda 2008, Borri and Camarda 2009, Camarda 2018, Santoro, et al. 2020, Santoro et al. 2021). In particular, they aimed to explore the possibilities of support offered by digital systems, mainly to broaden the arena of participants by including expert and non-expert knowledge to generate multi-agent knowledge bases accessible in real time. The case of the industrial city of Taranto (Italy), in this context, has provided the possibility of hybridizing the traditional future-workshop approach with a more proactive support of digital technology (Camarda 2018). The work was part of the 2014 process for the drafting of the urban Master Plan, thus being forced within limited time

limits. With the aim of more effectively managing the need for synthesis and refinement of results in real time, the interactive process was supported by the use of concept maps and wordclouds (Cui et al. 2010, Heft 2013). The process involved approximately 350 participants, divided into 8 sessions carried out throughout the city's neighborhoods. It was limited only to the stages of identifying problems (critique) and generating desirable future images (fantasy) for the development of the city. The output required by the official research contract was the provision of concepts and keywords on which the municipal administration would subsequently develop strategy schemes. An example of the session relating to the compact city, i.e. the Taranto shopping centre, is shown with the concept maps (figure 4) and the synthetic wordcloud (figure 5) of the problems cited by the participants.

Figure 5 – Wordclouds of problems in Taranto process - original Italian excerpts (Camarda 2018)

The use of a collective visualization tool such as concept mapping usefully supported idea generation. The tool also allowed a reflection on the relationships existing between the various problems - which are not shown in the figure because it would have been illegible. It also allowed further stages of exchange and collective refinement of the statements, for a process of iterated self-learning that is very useful in generating high-level knowledge (Lichtenstein 2000, Allee 2009). However, the very visual appearance of figure 4 shows clear problems of synthesis and unmanageability of the reflections, which paradoxically grow with the (desirable) increase in the reflections themselves. To deal with these problems it was decided to synthesize the statements using keywords, subsequently collected by frequency and redundancy via wordcloud. This process was reiterated for all 8 neighborhoods of Taranto and provided to the municipality for subsequent deliberations. This case can show that the need to preserve the complex richness of statements, towards a more effectively knowledge-based decision-making process, risks being challenged by the needs for readable synthesis and manageability of the results.

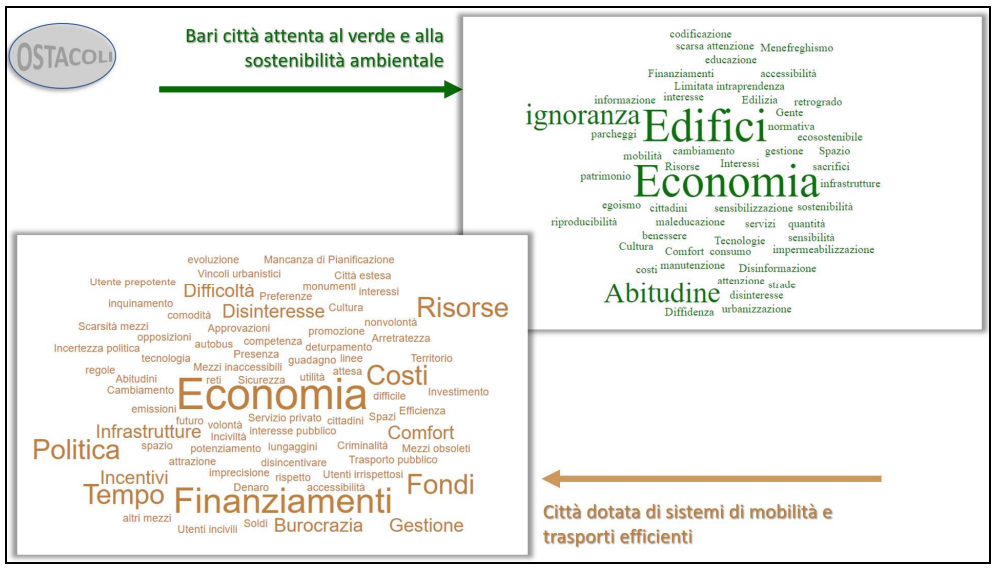

Figure 6 – Wordcloud of obstacles in university experimentation - excerpt in Italian (Santoro, et al. 2020)

An attempt has recently been made to extend these keyword-based synthesis approaches, oriented towards the automatic processing of knowledge data, to a complete process of future workshops - held remotely (Santoro, et al. 2020). The opportunity emerged during the COVID-19 lockdown of 2020, when the SB exercise usually carried out by the students of one of our Spatial planning classes had to take place completely remotely. In that case, the continuity of the process could only be guaranteed by the use of adequate real-time PC-based knowledge collection, exchange and synthesis approaches. In this case the experimentation involved approximately 130 students, who simulated being stakeholders in the process of drafting the Master Plan of Bari (Italy). The exercise strictly followed the standard process and ended in three sessions of 2 hours each, carried out on two consecutive days during the official class time. The limited time and availability of the students forced us to resume the synthesis solutions tested in Taranto, and an example shows the outcome of the stage of identifying the obstacles to development (figure 6). A summary of the outcomes of the process for one of the future visions is shown in figure 7.

Bari city of green and environmental sustainability		
Obstacles	**Policies**	**Resources**
citizenship mentality	communication strategies that raise awareness among citizens to adopt more sustainable actions	human
lack of space management	collaboration strategies between different types of actors that converge in common actions to redevelop existing areas	human/financial
lack of funds	writing projects to receive funding	human/financial

Figure 7 – The scenario built in university experimentation - English translation (Santoro, et al. 2020)

In this case, the students were asked to complement their statements for each step of the process with keywords selected by themselves. The objective was to minimize the risks of external interpretation in the moments of summarizing the responses necessary for data processing. However, this synthesis carried out by each participant did not prove to be entirely representative of the thoughts expressed. Perhaps the problem was in the absolute homogeneity of the participants, who had no real motivation to support their claims as stakeholders. The result was synthetic pictures that were not very representative, and above all a synthesis of the strategies for realizing the chosen vision (Bari, a city of green and environmental sustainability) which provided a scenario that was too brief and very general (Figure 7). However, in general this experimentation has shown that remote PC-based implementation is now reliable for supporting SB activities including extended and delocalized communities. Familiarity with technologically mediated interaction environments is now widespread, so as to avoid the 'cold interaction' effect that made the first experiences of this type ineffective (Khakee et al. 2002). Experimentation now highlights the problems of structuring knowledge databases - interactively and iteratively realized by the participation process. This circumstance risks underestimating the rich complexity of the knowledge exchanged and, consequently, not adequately supporting the decision-making and/or planning processes.

3.3 GPT-based scenario building

A comparative reading of the various SB experiences over time shows some interesting characters. The so-called future-workshop approach aims to define alternative strategic scenarios explicitly. The defined path (critical issues - visions - obstacles to visions - policies to overcome obstacles - resources to support policies) typically develops according to a fairly consolidated and replicable layout. The structuring in consecutive stages allows moments of reflection, expression, comparison, analysis and partial and integrable synthesis. This scheme stimulates the development of an aware and dynamic knowledge base, a useful evolutionary mirror of the community analyzed (REF...). However, knowledge emerges in different ways. On the one hand it is able to express a significant substantive richness, with detailed argumentative articulations and also with useful abstraction - within the expressive limits of an essentially written language. On the other hand, it is certainly a knowledge attracted and influenced by explicit purposes linked to the strategic process and the scenario objective, which tends to filter the contributions in strict coherence with this orientation.

Furthermore, it is a knowledge strongly conditioned by the presences (and absences) of the different agents, which add further relevance to the specific orientation (Chen et al. 2020). The management of complex multi-agent knowledge represents one of the major challenges of recent research, to which the development of information technologies is increasingly trying to give support. Just the emergence of these forms of regularity and replicability of this step-based and scenario-oriented model of cognitive interaction suggests an exploration of the potential support of artificial intelligence for scenario building (AISB). This chapter aims to investigate the potential usefulness of involving simple AI agents within a SB process. In particular, the experimentation shown here was an attempt to apply the future-workshop approach in an interaction with an AI unit - in this case the Copilot search engine equipped with OpenAI's chatGPT. In essence, the interaction develops as a sort of scenario simulation to support the development of an urban Master Plan for the city of Bari, in Southern Italy. Given the essentially exploratory nature of the initiative, it was decided to develop that pilot experiment by identifying a restricted arena of stakeholders. The system presents some limitations imposed by the institutional contract between the operating platform and the Polytechnic. In fact, the maximum number of characters for each search string is set at 4,000 characters, with a maximum of 30 query interactions with Copilot. In this context it was therefore difficult to develop a unitary and structured path. What is shown here is the result of a series of partial processes reiterated several times and recomposed in an integral way.

After an analysis of the protocols of various activities carried out in the past, eight different profiles were selected from the most recent ones who participated in the various meetings. They are a farmer, an artisan, an entrepreneur, an environmentalist, a 6-year child, an elderly person, an artist, an influencer. The interaction took place by asking the artificial intelligence for each stage to simulate itself as each different stakeholders listed in each question. The stages followed the typical layout of the future-workshop approach (figure 8a), and each step was developed according to an iterative sequence (figure 8b).

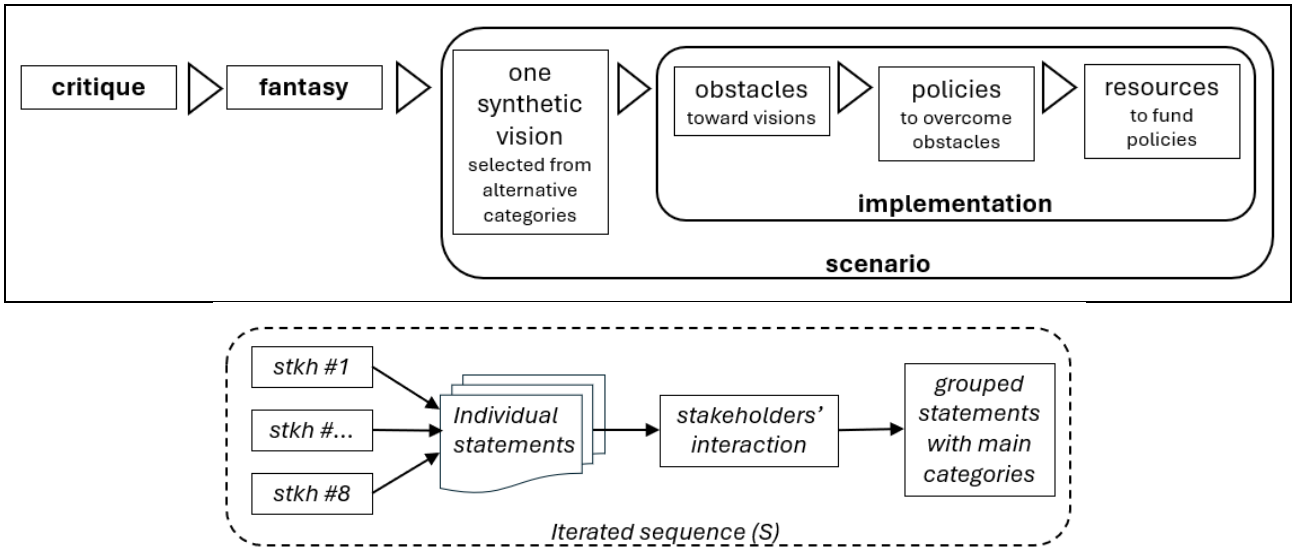

Figure 8 – (a- up) Layout of the future-workshop approach; (b- down) iterative sequence of each stage

This iterative sequence consists of standard questions, from which individual statements emerge following the characters of each agent profile. This question is put down as follows: “Imagine yourself as an entrepreneur living in Bari (Italy), called to help making a new Plan of Bari for the next 50 years. Through statements, figure out some worded images to express your desired futures of Bari. Each statement should explicitly and individually include its relevance for an entrepreneur stakeholder”. To this question, GPT answers with a series of statements, allegedly consistent for each stakeholder, as in the example of the visions desired by the artisan: “Creativity and innovation hub for artisans' collaboration; cultural heritage and diversity with newness; green and sustainable city with eco-artisans; vibrant and inclusive community of artisan contributors; smart and connected city for artisan information”. In the traditional SB process, at this point the various statements are shown to all participants, who can modify or integrate positions based on the new knowledge exchanged. This step required an extended computational capacity of the system and therefore was not implemented due to the technical limitations described above. Then in the next step all statements were grouped according to synthetic categories named through labels, which were listed in order

of shared importance. In particular, the query to GPT has been put down in these terms: “Imagine the knowledge team composed of a farmer, an artisan, an entrepreneur, an environmentalist, a 6-year-old child, an elderly person, an artist, an influencer, all living in Bari (Italy). After a motivated discussion with one another, how do you think would the multiagent team group all the statements? Is there a possible shared ranking made by the multiagent group altogether, in terms of importance that takes into account their typical stakeholder's profiles?”. The attempt was to put the GPT in a position to make a synthesis using criteria consistent with the agent profiles involved. The result of this second step was a list of labelled synthetic categories, including the relevant individual statements and sorted according to decreasing importance. The typical response for each stage of SB, in the example of visions, is as follows: “Based on the common themes and keywords, I will try to propose a possible grouping and ranking that could reflect the collective vision of the team for the future of Bari, following each stakeholder's profile: 1) Green and resilient Bari […]; 2) Innovative and creative Bari […]; 3) Inclusive and social Bari […]; 4) Opportunity and mobility Bari […]; 5) Bari's identity and vision […].

At the end of the process, a future scenario was generated relating to the vision of Green and resilient Bari, including the possible operational strategies to achieve it. The entire process simulation session lasted approximately three hours, including time for database reorganization between one stage and the next. However, considerable additional time was necessary to train the system to provide answers consistent with the questions asked and with the overall context flow. In fact, as we said before, the system does not allow extensive computations and therefore needs manual chaining between queries that require additional operations. The overall duration can therefore be estimated at less than ten hours in total.

A specific reflection in this sense concerns the interaction mechanism between user and system. It is known that GPT models are based on transformer architectures, deep learning models, attention mechanisms and neural networks evolutions (Vaswani et al. 2017, Wang and Biljecki 2022). They are able to process natural language by creating an interface to input queries and collect subsequent results - instead generating natural language content in the final reverse path. In this context it was necessary to proceed with a sort of calibration of the interface which caused the time problems highlighted above. However, this need for repeated modification of the queries also made it possible to bypass some 'policy limitations' of the system, as in the case of the request to sort the labelled synthetic visions. In fact, initially it was impossible to hierarchize the visions in terms of common importance for the multiagent team, because GPT declared that it "did not feel it had the authority" to use criteria for evaluating the importance of the visions for the future of Bari. Using various re-elaborations of argumentation, in the end the system provided the appropriate answer. In particular, the arguments aimed to underline the simulation aspect of the task, disaggregated the questions into incremental packages (run ranking for each stakeholder, run shared ranking in abstract terms, run shared ranking for Bari), as well as reminded that the team is made up of stakeholders representing community interests and not political interests. The importance of query argumentation therefore proved to be central, time demanding, process challenging and with a significant role played by manual operations.

Another element to point out is the importance of the underlying calculation models. As is known, GPT models use stochastic sampling during response generation, with an intrinsic randomness mechanism that explores and selects data and documents also depending on their frequency and availability. This is also one of the points of major debate today, regarding the influenceability of the system (Floridi and Chiriatti 2020, Schlagwein and Willcocks 2023, Wolfram 2023). In our case, for example, when asking for the generation of future visions we had to review the questions several times, limiting the citation of "Bari Master Plan". This is because in the absence of limitations GPT especially oriented its research to the formal documents of Bari's new strategic plan, available on the internet in large quantities, and minimized broader references. On the other hand, this laborious operation was also possible thanks to an appropriate transparency mechanism of GPT, which often cites the documentary sources used.

In general, the AI-generated scenario building (AISB) process provided apparently coherent scenarios from a logical, formal and even substantive point of view. The extent to which the contents generated can have real relevance in a decisionmaking and urban planning perspective is indeed a problem yet to be duly explored. In the following chapter some conclusions will be drawn in this regard, also in relation to the comparison with the SB processes carried out so far and partly shown in the previous examples.

4 DISCUSSIONS AND CONCLUSIONS

The overall objective of this work is to explore multi-agent knowledge exchange and management architecture systems to support informed decisions. The paper was oriented to explore the potential usefulness for decision making and spatial planning of a future SB process using artificial intelligence. The work first briefly framed the scenario building methodology within a spatial planning area of interest. Subsequently, some reflections were reported regarding experiences made by our group over the years on the construction of scenarios. Finally, an experiment carried out with the GPT Copilot module was reported, to lay out an SB process through artificial intelligence (AISB).

First of all, it must be said that the current evolution of the GPT model uses a natural language processing module, which is also interesting from the point of view of the logical articulation of the levels of expressed content. In fact, the depth of the responses in AISB appears to be sufficiently significant and not superficial. It appears (generally) consistent with the context of the question and with the profile of the simulated agent - although often (but not always) decontextualized with respect to the places and tending towards abstract contents. On the other hand, in SB the answers are not always significant and profound, not always coherent with the context of the question (the cogent interest of the agent can lead to digress) and often rooted 'in concrete feet' on localisms of small scales. In this regard, the '0' stage of critique, born with the psychological objective of exposing the critical issues of the area that weigh on the agent (with the aim of circumscribing them and allowing the subsequent imaginative stage to emerge without burdens), obviously does not doesn't make much sense in AISB which is pure documentary simulation. This stage was therefore retained only for the comparability of the approaches.

From a procedural point of view, a complete real SB takes a long time (our experiences report an average of 2-4 days), while AISB takes a few hours to manage and organize the responses. Here, however, it is necessary to remember that in AISB the frequent contextual, semantic and/or substantive inconsistency of the answers implies manual reiterations from the outside to calibrate the question-answer cycle so as to find the question asked in a coherent way (but how much does the inevitably interpretive force of such external incursions impacts on this cycle?).

From a substantive point of view, both SB and AISB approaches manage knowledge with relevant levels of complexity with the aim of attributing (future-oriented) degrees of structuring to the processed databases. However, the usual SB activities manage real interactive multi-agent knowledge, while this AISB experimentation represents a simulation of multi-agent cognitive elicitation by GPT - with the help of an external knowledge engineer. While real SB collects and exchanges a database of original and differentiated (real multiagent) knowledge, AISB collects and adapts pre-existing knowledge, reinterpreted through machine learning protocols.

These circumstances are both relevant to the topic of decision support systems - which is the context of this research. In fact, AISB could apparently act as a DSS, being able to manage a dynamic construction of scenarios in real time (albeit with an external step-by-step control of the congruence of the question-answer cycles and related problems of the interpretative filter, as mentioned before). Yet remains an intrinsic problem of knowledge fed and updated casually, pre-existing, formal, traditional, perhaps trivial and obvious. There are no sensations, emotional aspirations, knowledge constructed cognitively and not statistically - that is, everything that makes a participatory interaction important and intriguing is lacking (Chen, et al. 2020, Iwaniec, et al. 2020). With AISB formulated as in the aforementioned case, there is the risk of constructing biased scenarios detached from the real prerogatives of the community agents.

In the end, it may seem that this work opens up more questions than it would like to answer. The research assumption itself may appear artificial, since SB was created to enhance the role of multi-agent cognitive participation, while AISB is a formally similar process but without the same prerogatives. Perhaps more precisely, AISB could fall within the statistically inspired exploration methods of scenarios and trends, with a more structural focus on complex knowledge. The context in which it develops, however, is an extremely open framework in continuous, tumultuous technological evolution. The knowledge on which an AI-based system currently draws is now also moving more structurally towards integration with dynamic sensory databases and towards external, multisource and multiagent knowledge (Tafferner et al. 2023). Even the organization of the knowledge base could benefit from models that are more markedly conceptual and relational rather than essentially stochastic (Bateman et al. 2010, Palagin et al. 2023).

From these emerging dynamics an AISB could draw more relevant operational significance in terms of complex knowledge, raising its level of contribution towards a DSS architecture. Our group's lines of research will be oriented towards this direction as a follow up to the present work in perspective.

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Fostering Gender-sensitive Mobility: Recommendations in the Context of Carsharing

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1 ABSTRACT

Individual mobility behavior is influenced by various factors. Gender roles for example, have led to significant differences between the mobility patterns of women and men. Compared to men, women engage more in care work, are more likely to work part-time, and are less frequently able to access a private car. Women often take more frequent but shorter travel trips, longer trip chains, and fewer trips for personal reasons (Kawgan-Kagan & Popp 2018). In order to ensure fair mobility for different user groups, urban areas offer an increasing number of mobility options for navigating without a private car – be it on foot, by bike, using public transport, or other mobility services such as car-sharing. The latter especially, is becoming more prevalent in cities but tends to be used more predominantly by men rather than women. Placing the sole blame on car-sharing operators would be too simplistic. Often, it is regulatory or planning conditions that make it challenging to design car-sharing attractively for all genders. Car-sharing is still a niche product that too few people are aware of, and the location, proximity and service offerings play a crucial role, which are still inadequate. Reasons for this include the limited availability of parking spaces in both public and private spaces (e.g., underground garages), especially in cities. For women, proximity to the workplace and residence is particularly significant. Moreover, car-sharing is perceived as too expensive and complicated to be truly attractive, especially considering that women are often more economically disadvantaged than men and have more complex routes due to caregiving responsibilities.

This contribution addresses recommendations for action regarding car-sharing, targeting politics and operators, and specifying them through the lens of gender-sensitive mobility. Furthermore, gaps are identified where research on mobility and gender should continue to advance.

Keywords: gender, planning, recommendations, carsharing, shared mobility

2 INTRODUCTION AND STATE-OF-THE-ART

The discourse on mobility planning is increasingly incorporating gender issues. Gender as a social construct, assumes that a person finds themselves in different life circumstances, leading to varying opportunities. When discussing mobility in the context of gender, the focus is often on the disadvantaged mobility chances and inequalities faced by women due to associated roles. Despite women's increasing participation in the labor market, they still predominantly assume household duties and care for children and dependent relatives (Bundeskanzleramt 2021; Schneebaum & Mader 2013, Dribe & Stanfors 2007). This has led to a phenomenon known as the "Gender Mobility Gap," which is particularly evident in parenthood. Reasons for this include sociodemographic factors and responsibilities such as caregiving tasks, resulting in different mobility patterns for men and women (Dörrzapf, et al. 2023, Kawagan-Kagan & Popp 2018).

In the context of mobility sharing, especially in the case of car-sharing, inequalities become evident. Car-sharing, considered a key component of sustainable multimodal mobility, has the potential to replace multiple private cars, saving space and resources in public areas. However, studies indicate that users of various (E-)car-sharing services currently concentrate on specific sociodemographic population groups, representing the "classic" early adopters, which are a majority of male users, above-average educational levels and younger users (Amirnazmiafshar & Diana 2022, Hülsmann et al. 2018, Stadt Wien 2015)

Carsharing is still a niche product. A representative survey shows that only 5.9% of men and 1.2 % of women are heavy users of carsharing in Austria. In total, 10.6% of men and 6.6% of women have had an experience with carsharing. Most of them live in metropolitan areas; in rural areas, the density of use is even lower due to the lack of supply. In the case of station-based car sharing, however, this can vary between locations. While at one location in a small town the gender ratio is balanced, at other urban locations more than two thirds are men. Possible reasons for a more balanced distribution of users in the smaller municipality could be that people from rural areas are more accustomed to driving cars in contrast to city

dwellers. It is assumed that the shared vehicles in the small town serve as a replacement for a second car (Statement MO.Point, 2024).

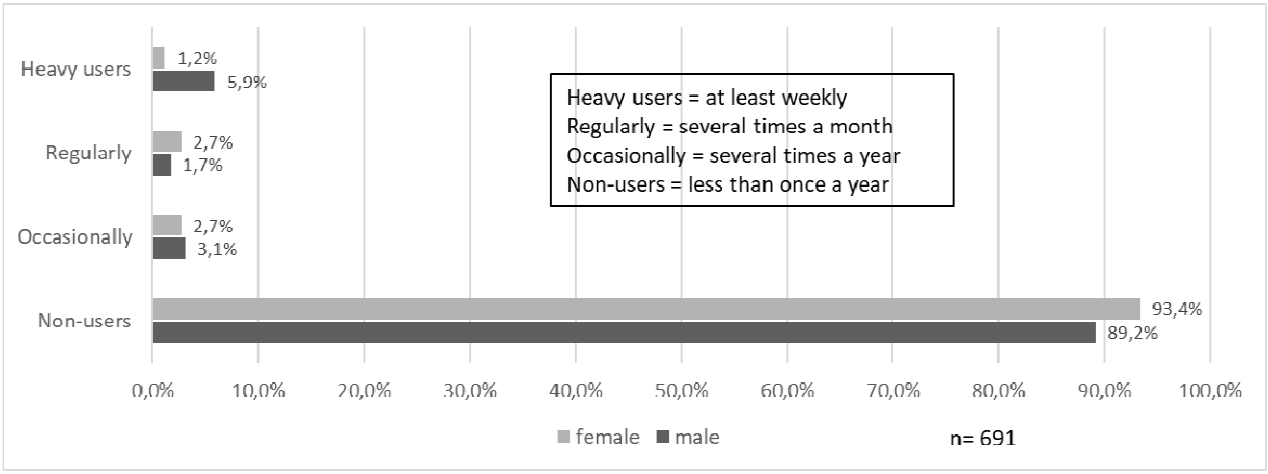

Figure 1: Frequency of carsharing use (own illustration, GECAR project survey, 2023)

For women, the reasons expressed against car sharing are somewhat different than for men. Men and women differ significantly in "Don't trust myself/don't like driving other people's vehicles" and "Afraid of operating other vehicles". Costs play an equally important role, even if the literature assumes that men pay more attention to cost and women more for frequency of the service and the environment (Sansonetti & Davern 2021). Owning a car is both the main reason against car sharing, but also the greatest potential for abolishing car ownership.

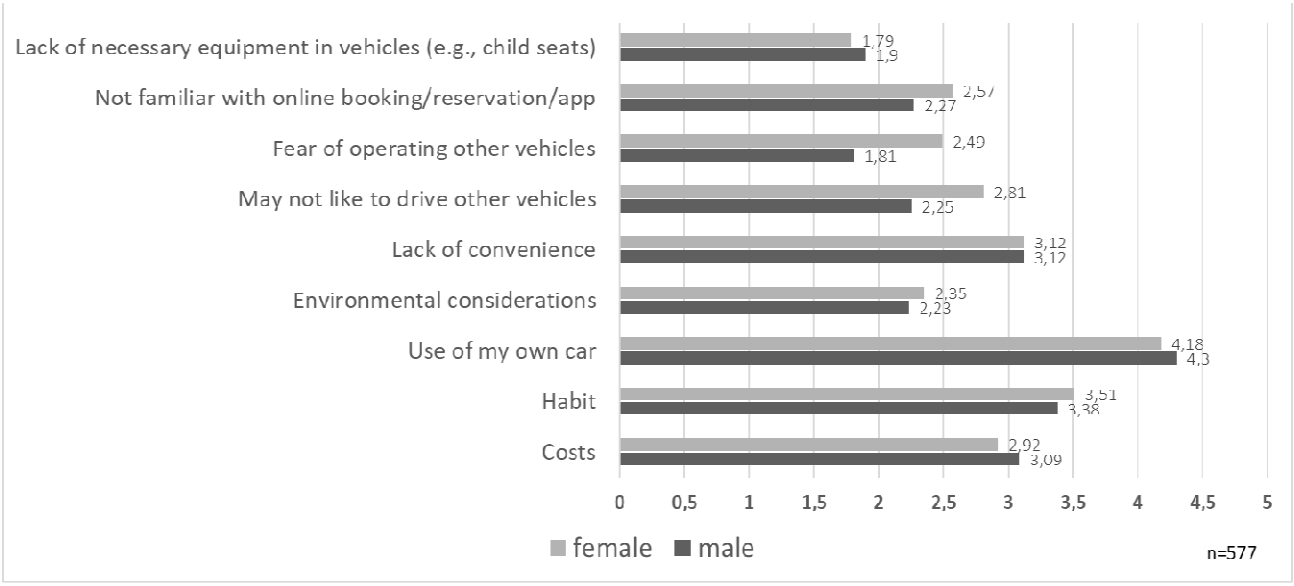

Figure 2: Reasons against car sharing among men and women (own illustration, GECAR project survey, 2023)

The reasons for choosing carsharing are also diverse. Women and men do not differ significantly in all areas, meaning that these variables do not have any major significance for carsharing users. Nevertheless, it is clear that men consistently rate carsharing more positively than women. Flexibility and cost efficiency are most important for both genders.

3 GOALS OF THE PROJECT AND METHODOLOGICAL APPROACH

In the research project “Gender-sensitive (E-)carsharing”, gender-specific (non-)usage behavior and barriers to the use of E-carsharing services in Austria were investigated. The project focuses on potential future target groups for E-carsharing, individuals who currently do not use the service but meet the basic requirements to integrate E-carsharing into their daily lives. In terms of gender-specific usage needs, the project places women in different life situations at the center of its research interest. Derived from the findings, gender-

sensitive measures for various (E-)carsharing services are subsequently developed in collaboration with (non-)users and operators.

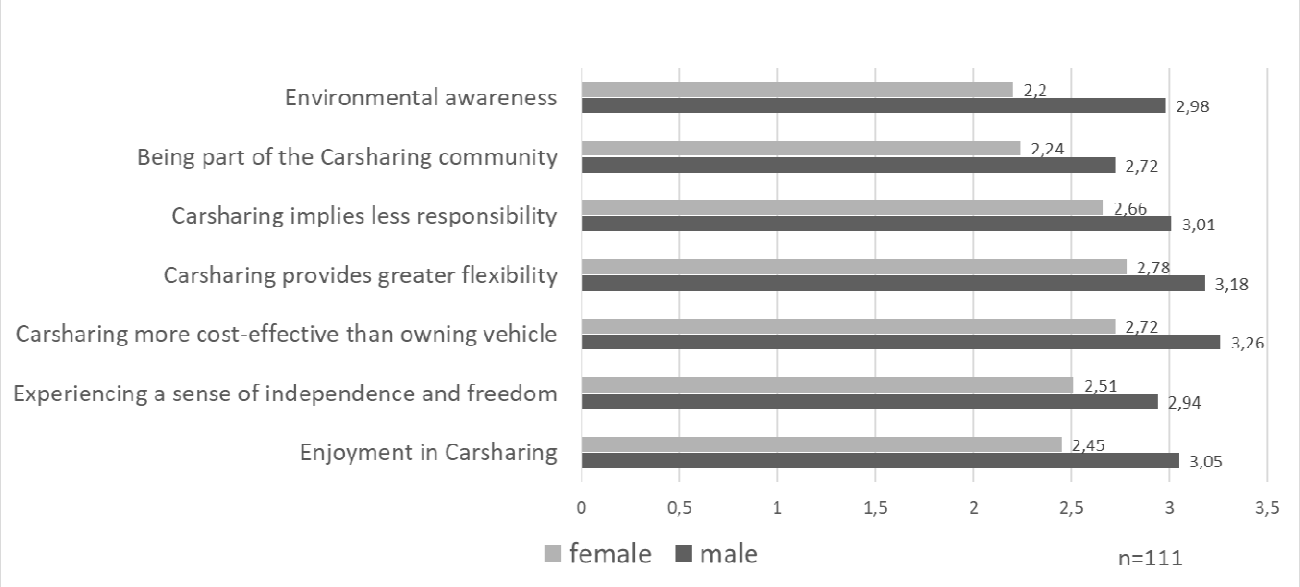

Figure 3: Reasons for car sharing among men and women (own illustration, GECAR project survey, 2023)

The formulated recommendations from this project operate under the assumption that reducing private car ownership is a central goal of (E-)carsharing. Therefore, the primary target groups are individuals contemplating the elimination of their existing private vehicle or considering carsharing as an alternative to purchasing a car. carsharing is viewed as a substitute for private cars and not as an alternative or competitor to using public transportation, bicycles, or walking, aligning with the predominantly car-critical stance of the women in the GECAR accompanying groups.

Within the research project GECAR – Gender-sensitive E-carsharing, co-creation groups were established by the project team in both Vienna and Bregenz. In Vienna and Bregenz, women in various life situations were recruited. In Bregenz, women who are members of the association Maronihof were also part of the group. These groups actively accompanied the research project throughout its entire duration through focus group workshop sessions. During these sessions, participants had the opportunity to contribute their knowledge, experiences, and ideas regarding improvement suggestions related to E-carsharing, to provide feedback on available services, and to test both offers during test phases.

A group comprising women was established to generate recommendations for carsharing operators and explore alternative ways of vehicle sharing, such as private carsharing. The groups included a total of 21 women between the ages of 28 and 61 years old. Slightly more than half of the participants had their own car in the household.

Location based carsharing		
Specification	Commercial carsharing, several locations in the urban area	Carsharing as association, mostly one location in the neighborhood
User group	Large, unspecified user group	Small user group (30-40 persons)
Available vehicles	Different vehicle types, predominantly e-cars	Different vehicle types (3-5 in the “pool”)
Network	No social network	People know each other, central contact person
Example in the project	MO.Point	Maronihof
Location	Vienna, AT	Bregenz, AT

Table 1: Two location-based carsharing use cases in the project

The cooperation partners MO.Point and the Maronihof association were involved in the project. In Bregenz, the Maronihof operates as an organized association, primarily serving residents of a specific neighborhood. The Maronihof consists of around 40 families and has four distinct cars, three of which are provided by

private owners. Many of the Maronihof users are women (Source: Workshops conducted as part of the research project). MO.Point, as a station-based carsharing provider, is engaged in neighborhood/ residential-based shared mobility services (E-Cars, E-Bikes, E-Scooters, etc.) in Vienna and offers carsharing for all interested users as well as closed residential/ business complexes, where only residents have access to the vehicles.

4 RESULTS AND RECOMMENDATIONS

4.1 Women's assumptions and needs regarding carsharing

Carsharing is perceived as a complex endeavour, with the carsharing landscape in Vienna being particularly convoluted and presenting high entry barriers. The location of carsharing services in close proximity to one's residence or workplace is deemed significant. Additionally, the desire for a seamless combination with other sharing options is evident. It is assumed that there is a limited selection of vehicle types available within the carsharing framework. Registration processes are often restricted to a single individual, with no provision for changing drivers.

However, it is important to note that despite these challenges, carsharing is generally acknowledged as an environmentally friendly alternative to owning a personal vehicle. This recognition positions carsharing as a sustainable option in contrast to traditional car ownership.

There is a high demand for information among women, encompassing topics such as sharing practices, operating automatic vehicles, and charging electric cars. Women have expressed a need for precise and detailed information in advance as well as a desire for well-coordinated platforms for carsharing that ensure coherence across different services. Emphasizing cost savings compared to owning a personal vehicle is crucial, as women often perceive carsharing as an expensive mobility option. Additionally, the proximity of carsharing locations to residential or workplace areas is considered important by women when choosing such services.

Based on insights from the GECAR research project, the following recommendations are proposed for enhancing women's access to (E-)carsharing:

4.2 Overarching Recommendations

The project encountered challenges as many concerns raised by women could not be addressed by the operators. Consequently, overarching recommendations, crucial for the further diffusion of the carsharing principle, are proposed at the political level. While the Austrian Sharing Strategy partially incorporates these recommendations, it lacks explicit consideration of gender-specific issues. From the perspective of the accompanying group, key priorities include: Firstly, a need to expand (E-)carsharing locations, ensuring a broader coverage to make these services easily accessible in daily life. This strategic expansion aims to make carsharing more relevant, particularly for women.

Simultaneously, efforts should be directed towards extending the infrastructure for electric vehicle charging in both urban and rural public spaces. This expansion is pivotal in positioning electric vehicles as a practical alternative to traditional combustion engine cars. Additionally, making private charging stations, such as those at hotels, publicly accessible contributes to a more widespread adoption of electric vehicles.

Addressing the need for convenient parking is crucial, especially for E-carsharing. Providing an adequate number of parking spaces in public areas, with a particular focus on underground facilities, ensures seamless access to carsharing services.

Tailoring carsharing offerings to the specific use cases of women is essential. This involves establishing cost-effective carsharing models that act as a "bridge" between urban and rural areas. This approach is particularly relevant when the car is needed primarily for overcoming distances rather than on-site requirements. Actively promoting these tailored offerings can boost adoption.

Lastly, illustrating the various benefits of transitioning from private, potentially outdated vehicles, to carsharing is key. Emphasizing cost savings through tools like cost calculators and real-life examples, highlighting CO_2 reduction using a Carbon Footprint calculator, and underlining the convenience of avoiding vehicle maintenance responsibilities, including service and tire changes, will play a vital role in promoting the advantages of carsharing.

4.3 Promotion and awareness – Putting Women as the Target Audience of Carsharing into Focus

A positive self-assessment regarding driving electric and automatic cars is essential to consider (E-)carsharing as a viable option. This requires knowledge and experience with this form of mobility, as well as general awareness of the offerings and their conditions (e.g., registration, booking, etc.). To embed such experiential knowledge broadly throughout the population, it makes sense to do this at various levels in a user-friendly manner. One possibility is to integrate information and opportunities that promote trying out carsharing could prove useful during the process of obtaining a driver's license, particularly for reaching future generations of drivers. Information sessions at institutions like community colleges could contribute significantly to broadening general knowledge and awareness of carsharing.

To make carsharing more appealing, there should be a deliberate focus on highlighting moments when it becomes particularly interesting for women. This could include scenarios such as transporting heavy goods or embarking on rural excursions. By showcasing these specific use cases, the marketing materials can effectively communicate the practicality and relevance of carsharing in diverse situations that women may encounter in their daily lives.

Promoting carsharing in combination with other sharing services, such as (cargo) bikes, can also significantly enhance its attractiveness. Aligning with the growing aspiration for environmentally conscious and multimodal transportation among many women and other population groups, this approach positions carsharing as part of a broader sustainable lifestyle. Emphasizing the synergy between different sharing services reinforces the idea that carsharing complements other eco-friendly modes of transportation, contributing to a holistic and environmentally responsible lifestyle.

4.4 Use and selection of vehicle

Firstly, it is crucial to offer a diverse range of vehicle types tailored to different occasions and needs. This includes multi-seaters for family outings, compact city cars that require minimal parking space, vans, and robust cars suitable for traveling with children, even if it involves some dirt. This variety ensures that women, among others, can choose a vehicle that aligns with their specific requirements at any given time.

Additionally, providing precise and detailed information about electric and automatic cars is essential. Women need to thoroughly familiarize themselves with various aspects, such as the vehicle's operation, charging process duration, and range in different seasons. This information should be easily accessible on both the website and the app, enabling users to make informed decisions.

Recognizing the potential limitations of digital access, it is advisable to have compact and clear information available within the vehicle itself. This analog form of information ensures that users can access essential details even when there is no internet connection, or the phone is unavailable.

Moreover, offering detailed information about specific vehicle features is crucial. This includes details on child seats for different age groups, vignettes, parking permits, parking tickets, and the size of the cargo space. Providing comprehensive information on these aspects contributes to a seamless and convenient carsharing experience.

Furthermore, ensuring an easy navigation system operation is paramount. Storing the "home location" of the vehicle in the navigation system enhances ease of use, and an overview of publicly accessible charging stations for electric cars nearby is particularly helpful. These features collectively contribute to a user-friendly and efficient carsharing experience, addressing the diverse needs and preferences of users, including women.

4.5 Locations and Accessibility

Clear and prominent markings should be established upon entering the garage and along the path to the parking space. Ideally, these markings should be well-lit and strategically positioned near the entrance for easy visibility. This ensures that users can easily navigate through the garage and locate their designated parking space with confidence. Additionally, providing this information digitally through the app is essential, but analog alternatives should also be available. In scenarios where the internet connection may be unreliable in an underground garage for example, analog information ensures accessibility, contributing to a seamless and reliable experience for users. Furthermore, ensuring sufficient space for straightforward parking and

exiting is paramount. Adequate space minimizes the risk of accidents and facilitates a smooth flow of vehicles within the underground parking facility.

4.6 Booking Platforms

Firstly, there should be good coordination and coherence between various platforms providing information, such as the booking app, website, and analog informational materials within the vehicle. Consistent and harmonized information is essential to minimize "drop-off moments" where users may encounter confusion or uncertainty and stop the registration or booking process. Additionally, if email confirmation is required during the registration and booking process, there should be clear notices in the web or app to guide users smoothly through the necessary steps. This helps in ensuring a transparent and straightforward onboarding process for users. Facilitating a change of drivers is another key consideration. The option for additional registered individuals to drive the vehicle is important, particularly during family outings or challenging traffic situations. This flexibility enhances the practicality and adaptability of carsharing services. Platforms should undergo regular reviews to identify potential "drop-off moments" and areas where improvements can be made. This proactive approach ensures ongoing optimization of the user experience, addressing any potential pain points in the carsharing process. Cost transparency in billing is crucial. Including a note indicating that the lowest tariff will always be charged ensures clarity and transparency in financial transactions related to carsharing services. Recognizing the importance of personal contacts for accessing the service, there should be a mechanism to involve friends and family members more actively. This social aspect enhances the user experience, creating a sense of community and safety, making the carsharing service more accessible and enjoyable for users.

To summarise, it can be said that there are various recommendations that apply at different levels of carsharing use. In principle, awareness and the availability of carsharing are very important. However, these recommendations reach a limit, as availability and especially locations for carsharing are part of a larger political decisions.

5 DISCUSSION – IS PRIVATE CARSHARING A VALID OPTION?

Within the groups and in collaboration with the Maronihof association, the possibilities of private carsharing for a small, delimited group were repeatedly discussed. In Bregenz, in the fall of 2023, a trial of private carsharing involving six individuals was conducted. This experiment consisted of two phases, with each phase involving the rental of cars from a dealership. The first test vehicle was an electric car; however, none of the six participants could find a suitable charging location. For the second test phase, due to the absence of charging infrastructure, a conventional combustion engine car was rented, placed in a public parking space in the neighbourhood accessible to all participants. Originally, a free app linked electronically with a key box was used for booking. However, the app was perceived as confusing for short time intervals (e.g., 30 minutes). As the key box could be used without the app, and the billing was already based on an hourly basis, the booking app was discontinued. Instead, participants began using Google Calendar for scheduling, and key handovers were arranged through leaving keys or coordinating via phone calls. Two women left the group during the second test phase, and three other participants did not have a need for a car during the trial period.

In Vienna, private carsharing was a recurrent topic, although there were no specific initiatives from the group participants. Nevertheless, the awareness of the subject was heightened. In cities, commercial carsharing is already on a good path. However, in rural areas, there continues to be a higher need for self-organization regarding mobility. These rural areas are characterized by a dependency on cars, high motorization rates, vast distances, and limited public transportation options. Additionally, facilities for local services, amenities, and employment are not uniformly distributed, and the population density is lower. As a result, mobility opportunities decrease – limiting options for moving from one place to another without a private car and impacting possibilities for social participation. Substantial research and implementation efforts are still required in addressing these challenges – especially initiatives to foster private carsharing and carpooling.

6 CONCLUSION

In conclusion, the research project "Gender-sensitive (E-)carsharing" sheds light on the intricate intersection of gender and shared mobility, particularly in the context of carsharing. The existing gender mobility gap and

disparities in the adoption of carsharing services among different demographic groups, predominantly favoring men, highlight the need for targeted interventions.

The project's primary goals were to investigate gender-specific (non-)usage behavior and barriers to the use of (E-)carsharing services in Austria, with a focus on potential future target groups. Through co-creation accompanying groups in Vienna and Bregenz, women in various life situations actively contributed to the research by sharing their experiences and insights.

The results emphasize that carsharing is perceived as a complex but environmentally friendly alternative to owning a personal vehicle. Women express a high demand for information, particularly regarding sharing practices, electric and automatic vehicle operations, and charging procedures. The gender-specific usage needs of women were central to the project, leading to the formulation of gender-sensitive measures for (E-)carsharing services.

The overarching recommendations highlight the importance of expanding (E-)carsharing locations for broader coverage, making services easily accessible in daily life, especially for women. Infrastructure enhancements, such as extending electric vehicle charging points and ensuring sufficient parking spaces, are crucial. However, these challenges can not only be tackled by carsharing operators and there is a need for policy strategies.

Promotional efforts should focus on positive self-assessment and awareness-building regarding driving electric and automatic cars. Highlighting moments when carsharing becomes particularly relevant for women, such as transporting heavy goods or rural excursions, can enhance its appeal. Combining carsharing with other sharing services like bikes aligns with the growing trend towards environmentally conscious and multimodal transportation. The research also delves into the viability of private carsharing initiatives, with practical trials conducted in Bregenz. While private carsharing poses challenges, particularly in terms of infrastructure and user experience, the awareness of the subject in Vienna and the acknowledgment of the higher need for self-organization in rural areas provide valuable insights for future initiatives.

In summary, the project contributes valuable insights and recommendations for making (E-)carsharing more gender-sensitive, inclusive, and accessible, addressing the unique needs and concerns of women in diverse life situations. Ongoing efforts in research, implementation, and promotion are essential for achieving a more equitable and sustainable mobility landscape.

7 ACKNOWLEDGEMENT

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Foundation for a Theoretical Framework on the Location of Manufacturing Firms in the Vicinity of Airports

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1 ABSTRACT

Manufacturing plays a crucial role in economic development. Peculiar geographical patterns of production are accordingly observable, wherein the environs of airports are some of the areas that accommodate the concentration of manufacturing firms. However, most of the literature on the placement of manufacturing firms relative to transport infrastructure focuses on road, rail and sea. The objective of this paper is thus to advance a foundation for a theoretical framework that analyses the spatial economic factors that influence the location of manufacturing firms in the vicinity of airports. The paper draws upon research conducted on the case study of the environs of Cape Town International Airport in South Africa. The analysis conducted in the underlying study explored the interconnections between the concepts of space, proximity, linkages, agglomeration economies, clustering and pattern. These concepts are accordingly used as building blocks towards the foundation for a theoretical framework. The contribution hinges on five layers of the economic space: the airport's environs, municipal area, functional region, other parts of a country and multi-country economic space. Different forms of manufacturing establishments' clustering, proximity and intensity of intra- and inter-firm linkages characterise these interrelated layers. The paper sensitises policymakers, spatial planners and authorities to the spatial economic dynamics of manufacturing firms situated near airports.

Keywords: Cape Town International Airport, airports, South Africa, industrial clustering, manufacturing

2 INTRODUCTION

Despite the transition to a service-driven economy in some parts of the world, manufacturing continues to play a paramount role in economic development (Haraguchi, Chen & Smeets, 2017; Naudé & Szirmai, 2012; Ndiaya & Lv, 2018; Pandian, 2017; Li, Xue & Huang, 2018). At particular periods in history, certain geographical patterns of manufacturing facilities are observable, and with the transition from one regime of production to another, the range of locational outcomes is extended. As shifts in manufacturing occur, a pattern of spatial responses is also discernible, spanning from the reorganisation of industrial areas developed in the earlier regimes of production to the establishment of new industrial nodes (Scott, 1988). These evolving patterns bring to the fore the importance of manufacturing facilities geography or locational patterns. It should be acknowledged that the problem of facility location (geographical positioning of facilities) has existed for a long time wherein it is argued that the appropriate location can, among other benefits, assist the firms to augment their operational performance (Chen, Olhager & Tang, 2014).

The paper intends to contribute to the literature on the location of manufacturing firms, with particular reference to the environs of airports. Discussions about the nexus between transportation technology improvements and land use recognise that airports can, at least in part, influence the geographical positioning of economic activities (Mokhele & Geyer, 2018), which could include manufacturing firms. Regardless of this acknowledgement of the influence of airports on the geography of economic activities, the majority of the literature on the connection between manufacturing facility location and transport infrastructure focuses on the impact of roads, railways and ports (Buurman & Rietveld, 2004; Holl, 2004; Rothenberg, 2011; Ghani, Goswami & Kerr, 2014; Xu & Nakajima, 2017). This focus on other modes shows a paucity of empirical literature on the placement of manufacturing firms near airports.

Using the study area of the environs of Cape Town International Airport in South Africa, this paper aims to contribute towards the foundation for a theoretical framework that analyses the spatial economic factors that drive the location of manufacturing firms in the vicinity of airports. The paper understands theory as a framework that assists towards conceptualising the phenomenon being analysed (Sayer, 1992), which is the spatial economic factors that influence the location of manufacturing firms in the vicinity of airports. This understanding contradicts a popular and at times misplaced position, which regards theory as a rigid framework for establishing laws and predictions (Wilson, 1992).

3 LITERATURE OVERVIEW: A CONCEPTUAL FRAME OF REFERENCE

The location of economic activities (such as manufacturing firms in the context of the paper) in the vicinity of airports can be analysed through the normative models of airport-led development, which are used worldwide to advance proposals on the idealised urban form of economic activities that are understood to be linked to or dependent on airports. A plethora of models of airport-led development include: aerotropolis, airport city, airport region, airfront, global transpark, airport corridor, airea, decoplex, aircity, aeropolis, aeropark, aviopolis, avioport, flight forum, sky city, airpark, aero city and aeroscape (Mokhele, 2018). Amid this extensive list, the model mainly used in contemporary literature and development policies (and more explicit on the location of manufacturing facilities) is the so-called aerotropolis. An aerotropolis is a sub-region wherein infrastructure and various components of the economy hinge on a major airport. The logic of the aerotropolis is that businesses in the region benefit from the speedy connectivity offered by the airport to suppliers, markets and business partners nationally and globally (Kasarda, 2019). An aerotropolis is anchored by a core airport area, responsible for providing logistics and transportation services. The airport area is surrounded by manufacturers and distribution facilities, which facilitate the quick transportation of manufactured products (Huo & Guo, 2021).

Several concepts are appropriate for analysing the location of economic activities in general, specifically those located on and around airports, and may be embodied in aerotropolis and other normative models of airport-led development. The concepts can also be applied specifically to the analysis of the location of manufacturing firms in the environs of airports. The concepts, which have historically been central to the analysis of the location of economic activities in human geography and allied disciplines include linkages, agglomeration economies and clustering. These are given substance by the associated concepts of space, proximity and pattern (Mokhele & Geyer, 2021).

Although the concept of agglomeration economies has historically received considerable attention in the literature, the work of Parr (2002) advances an all-embracing consideration of the concept, which is understood to be based on internal economies and external economies. The economies internal to the firm (categorised into economies of scope and scale) are controlled by the firm concerned and are not directly influenced by the activities of other firms. The concept of internal economies of scale, also known as horizontal integration, denotes benefits to the firm that result from increases in the extent of its operations. Internal economies of scope (lateral integration) are realised because of the firm's diversity of products and/ or services. The notion of economies of scope is based on the understanding that the undertaking of several activities by a firm could happen more efficiently than would be the case if different firms undertook such activities (Parr, 2002; Panzar & Willig, 1981). It is important to note that agglomeration economies based on internal economies do not necessarily influence a spatial concentration of related firms but result in the individual firms becoming large (Parr, 2002).

In contradistinction to internal economies, external economies are affected by the operations of other firms and are, therefore, beyond the total control of the individual firm (Parr, 2002). External economies comprise localisation economies, urbanisation economies, and activity-complex economies. Localisation economies emanate from the common location of independent firms in the same economic sector or industry. Though external to the firm, these economies are internal to the industry (Marshall, 1920). Urbanisation economies are characteristic of diversified urban areas, and result from the common location of firms involved in diverse and unrelated activities. Urbanisation economies, which are external to the individual firm and the industry or sector, are internal to the urban concentration. Urbanisation economies may therefore be understood as economies of scope - benefits from the scope or diversity of production and services within the urban concentration (Parr, 2002). Finally, activity-complex economies result from the common location of firms operating in a production and/ or service provision chain, forming an activity complex. These economies are mainly a result of the interrelatedness of firms. In this regard, a firm has backward or upstream linkages to the firms supplying it and forward or downstream linkages to the firms it supplies with the services or products/ goods. Activity-complex economies are therefore external to the firm but internal to the complex it is a member (Parr, 2002).

Linkages, which refer to the flows of information, materials and/ or services between and within individual firms, are essential for realising the different forms of agglomeration economies. The linkages of a firm can be classified into three categories: one, backward (upstream) linkages, which provide goods and/ or services as input for its activities or output; two, forward (downstream) linkages, which provide links with the

customers purchasing its products or services. If businesses are connected through an input-output (i.e. buyer and supplier) arrangement, the downstream industry forms the market for the upstream industry (Malmberg & Maskell, 2002; Porter, 1990; Venables, 1996). Therefore, the firms in such vertical arrangements are partners and collaborators (Malmberg & Maskell, 2002). The third category pertains to horizontal, lateral or sideways linkages, which are interactions with other firms or economic actors involved in the same processes and share the market (customers) and technology (Malmberg & Maskell, 2002; Porter, 1990).

The existence of linkages and the subsequent realisation of agglomeration economies can result in the clustering of manufacturing firms. Two interrelated categories of clustering, differentiated by spatial proximity, can be discerned in the literature. In the first understanding of what could be referred to as spatial clusters, clustering is defined as linked firms that are located in the same geographical area (Porter, 1990). Several categories of spatial clusters can be identified in the literature, including pure agglomeration, industrial-complex, and social-network (Gordon & McCann, 2000); Marshallian and Italianate industrial districts, hub-and-spoke industrial districts, satellite platforms, state-anchored industrial districts (Markusen, 1996).

In the second interpretation, clusters are understood linked firms, regardless of their separate geographical locations. These can be referred to as organisational clusters. The paper adopts the position that clustering can be based on agglomeration economies that are internal and/ or external to a firm. In terms of internal consideration, when the head office of a manufacturing firm has strong functional linkages with other units of the same firm, whether located within the same geographical area, city, country or even across national borders, such a situation would be regarded as organisational cluster emanating from internal economies.

As reflected earlier in the paper, agglomeration economies, linkages and clustering are given substance by the vague concepts of space, proximity and pattern. Unlike absolute space, which is essentially a fixed frame that contains economic agents and their activities, relative space is defined by the interrelations between economic agents (Friedman & Alonso, 1964; Garretsen & Martin, 2010), and in relational understanding, space does not exist without linkages and underlying relationships (Massey, 2005). Space cannot be comprehensibly understood without the concept of proximity or distance, wherein a distinction can be made between geographical and organisational proximity (Boschma, 2005). While geographical proximity refers to the physical distance between actors (such as firms), organisational proximity denotes the closeness of actors regardless of the physical distances between them (refer to the overview of spatial and organisational clustering earlier in this section). Finally, the activities of firms are understood to create particular patterns in absolute, relative and/ or relational space. Historically, the geographical pattern in absolute space comprised points, lines and areas, which are understood through the measures of, inter alia, point pattern, nearest neighbour analysis and quadrant sampling (Coffey, 1981). The paper is inclined towards an understanding that the spatial economic factors that influence the location of manufacturing firms in the vicinity of airports may not necessarily create observable patterns in geographical space.

The foregoing conceptual frame of reference was used to inform the empirical analysis and the findings that the paper draws on, as well as the subsequent contribution to the theoretical foundation that analyses spatial economic factors that influence the placement of manufacturing firms in the vicinity of airports.

4 STUDY AREA AND RESEARCH METHODS

The paper is based upon the study area of the environs of Cape Town International Airport (CTIA) in South Africa, which is situated in the City of Cape Town municipality, Western Cape province. The second busiest airport in South Africa, CTIA processed around 41 000 tonnes of cargo in the 2020/ 2021 financial year, which was a reduction from 68 191 tonnes in the preceding financial year (Airports Company South Africa, 2021) due to, at least in part, travelling restrictions associated with the Covid-19 pandemic. The development node around CTIA is one of the notable industrial areas in the municipality – hence it was considered suitable for analysing the connection between the location of manufacturing firms and airports. The beginnings of the concentration of manufacturing in the vicinity of CTIA can be traced to the 1970s and 1980s when the government attempted to promote industrial activity in the area by zoning the landholdings for industrial purposes. In 2021, 67 manufacturing firms were documented near CTIA (Fig. 1).

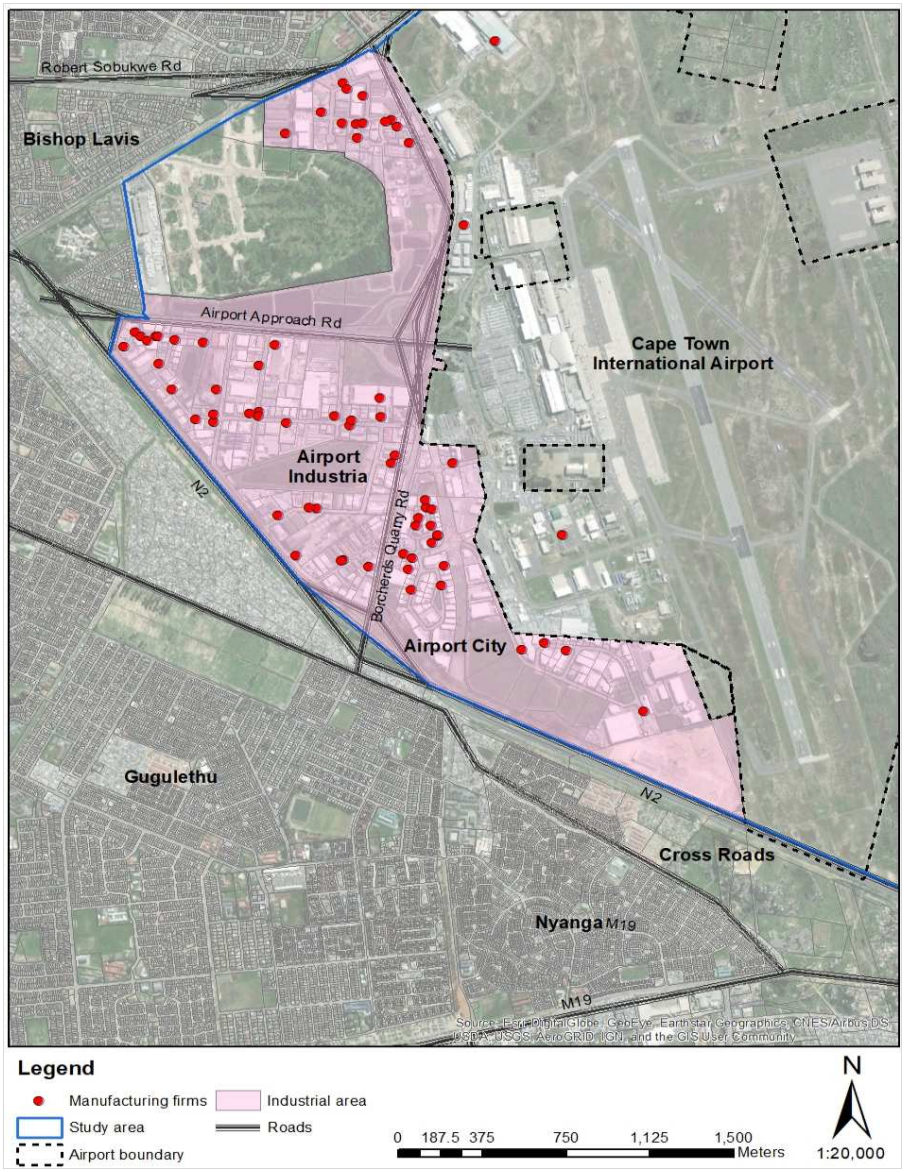

Fig. 1: Study Area.

The study the paper draws upon (Mokhele & Garatsa, 2023) was based on descriptive survey research, which generally intends to understand the population through investigating a sample. However, the literature recommends not applying sampling to a population of fewer than 100 units (Leedy & Ormrod, 2015). In this regard, because the population of the study area was 67, an effort was made to interview the representatives of all manufacturing firms in the vicinity of CTIA. Primary data were collected in November 2021 wherein the representatives of the firms were requested to respond to a structured questionnaire, which entailed a range of closed- and open-ended questions. The data were collected through face-to-face, self-administered and telephonic interviews. This combination was employed because some respondents were not willing or not available to participate in the preferred technique of face-to-face interviews. This situation that was worsened by the Covid-19 lockdown restrictions. Of the total population of 67 manufacturing firms in the vicinity of CTIA, 23 representatives (approximately 33% of the population) participated in the survey interviews.

5 A SUMMARY OF THE FINDINGS

The section summarises the research findings, which are used as a base for advancing a contribution towards a theoretical framework that analyses spatial economic factors that influence the placement of manufacturing firms in the vicinity of airports.

5.1 Overview of the firms

Informed by the data from the survey interviews, the manufacturing firms were categorised in terms of the divisions of the South African Standard Industrial Classification (SIC) (Statistics South Africa, 2012). Showing there was no distinct manufacturing specialisation in the vicinity of CTIA, the firms' business activities ranged widely, from the manufacturing of wood products to the manufacturing of fabricated metal products (Table 1).

SIC Manufacturing subcategories	Number of firms	Percentage
Manufacturing of wood and of products and cork	2	8.7%
Manufacturing of food products	2	8.7%
Manufacture of other non-metallic mineral products	2	8.7%
Manufacture of computer, electronic and optical products	1	4.3 %
Manufacture of machinery and equipment	2	8.7 %
Manufacture of furniture	1	4.3 %
Manufacture of chemicals and chemical products	1	4.3 %
Manufacture of textiles	1	4.3%
Manufacture of rubber and plastic products	3	13%
Manufacture of other transport equipment	1	4.3 %
Manufacture of motor vehicles, trailers and semi-trailers	1	4.3 %
Manufacture of chemicals and chemical products	1	4.3%
Manufacture of fabricated metal products	1	4.3 %
Other manufacturing	4	17.4%
Total	**23**	**100%**

Table 1: Activities of manufacturing firms located in the vicinity of CTIA.

It was essential to analyse the size of the manufacturing firms, using the number of employees as a rudimentary proxy for size. The following classification of the size of manufacturing businesses was used: micro (five employees), very small (20 employees), small (50 employees), and medium (200 employees) (South Africa, 1996). The findings revealed that close to half (about 45%) of the firms had between 1 and 19 employees, showing that most manufacturing firms near CTIA were very small or micro.

On the background of the size of the manufacturing firms, the majority (55%) indicated that they did not have a multi-office structure, whilst 46% reported that they had a multi-office structure, showing that manufacturing firms on and around CTIA were mainly small or micro stand-alone firms. The majority (70%) of the firms with multi-office structures were branches, 20% were subsidiary firms, and 10% were head offices. It was discovered that 31% of the headquarters of the branch firms located in the vicinity of the airport were located across different areas of South Africa, and only 9.1% of the firms were subsidiaries whose parent firms were situated beyond the borders of South Africa, reflecting that the presence of multinational manufacturing firms was minimal in the vicinity of CTIA.

Contact between the branches and their headquarters and subsidiaries with their parent firms was analysed to discern the prevalence of intra-firm linkages crucial for the generation of internal economies described in the Literature Overview section. Showing the presence of dense intra-firm linkages within the economic space that is not restrained by geographical space or physical distance between head offices and (other) branches, the findings revealed that, on the one hand, 41% of the branch or subsidiary firms communicated with their headquarters daily and on the other, 32% made contact with other branches daily.

5.2 Linkages, agglomeration economies and clustering

5.2.1 Linkages with the airport

The linkages between manufacturing firms and CTIA establish, at least in part, the importance of the airport on the location and operations of the firms and the existence of urbanisation economies. More than half (57%) of the firms used CTIA for airfreight (shipping) purposes, i.e., to receive raw materials/ input for manufacturing activities and/or ship manufactured products. It was essential to analyse the frequency of the utilisation of CTIA to establish the level of the airport's importance on the activities of the manufacturing firms. Most firms (31%) received raw materials and/ or shipped their products through the airport at least every three months, while a smaller number (representing 15%) used the airport on daily, weekly and yearly, respectively. A much smaller number (constituting 8%) of the firms seldom used the airport, only once per month. The findings depict that the majority of the manufacturing firms did not use CTIA frequently, suggesting that the firms possibly used other modes of transport to interact with suppliers, distributors and/ or buyers frequently.

5.2.2 Linkages with firms in the vicinity of CTIA and elsewhere

As agglomeration economies rely on linkages, it was essential to analyse the inter- and intra-industry linkages of the manufacturing firms located in the vicinity of CTIA. The interaction between firms in the economy reflects a peculiar relationship, involving a balance of competition and cooperation (Belussi & Caldari, 2009). The findings revealed that more than three-quarters (78%) of the manufacturing firms had business interactions with other firms in the study area, i.e., the neighbouring firms. These geographically proximate linkages within the study area reflect signs of a possible spatial cluster/ industrial district of manufacturing firms.

Despite the aforementioned dense business linkages within the study area, the findings revealed that face-to-face engagements were not necessarily a precondition for business interactions, as less than half of the firms (42%) relied on face-to-face engagement with neighbouring establishments. The findings bring into question, at least in part, scholars who assert that face-to-face interactions are a prerequisite for the effective coordination of economic activities (Storper & Venables, 2004).

The manufacturing firms confirmed they had business relationships with the neighbouring involved in a several sectors, including manufacturing, transportation storage and logistics, and wholesale and retail. More than half (54%) of the manufacturing firms had business interactions with the neighbouring transport, storage and logistics firms, possibly for transporting the input and/ or finished products. 14% of the firms indicated that the business interactions were with the manufacturing firms near the airport, depicting the existence of intra-industry linkages, which could potentially result in localisation economies. As discussed in the Literature Overview section, drawing from the seminal work of Marshall (1920), localisation economies are benefits that result from the co-location of businesses in the same industry or economic sector. In this regard, the interactions of manufacturing firms in the vicinity of CTIA reflect the possibilities of localisation economies that stem from intra-industry linkages.

Intra-industry and inter-industry interactions of the manufacturing firms in the vicinity of CTIA included sales, marketing, procurement, transport and logistics, and repairs and services. The majority (56%) of the interactions involved activities related to transport and logistics. Services and repair constituted 13% of the interactions between manufacturing and neighbouring firms. Sales, marketing, and procurement constituted a small percentage (6.3%) of the interactions between the manufacturing firms and the neighbouring firms in the vicinity of CTIA.

It was also essential to analyse the existence of subcontracting to, at least in part, further discern the extent of inter-firm linkages of the manufacturing firms across different geographical scales. Subcontracting is a contractual relationship in which one firm conducts commissioned work on behalf of another firm (Kimura, 2002). Subcontracting benefits the involved firms through, among others, wage and cost savings (Holl, 2008). By nature, subcontracting between firms enhances inter-firm linkages that could lead establishing industrial clusters/ districts if the linkages occur within the same geographical area. Approximately 61% of the manufacturing firms subcontracted the services of other firms, while 52% of the firms subcontracted their services to other firms.

The literature argues that firms, which are located in industry agglomerations, are inclined to utilise subcontracting (Holl, 2008), hence it was essential to ascertain the geographical location of the firms that subcontracted their services to the manufacturing firms located in the vicinity of CTIA and vice-versa. The manufacturing firms noted that the majority of the firms (47%) that were subcontracted were located elsewhere in the City of Cape Town municipality, and 21% of the firms were located in the vicinity of CTIA, in part showing signs of spatial clustering. About 5% of the subcontracted firms were situated beyond the borders of South Africa. It is noted that the manufacturing firms located in the vicinity of CTIA were more related (i.e. from a subcontracting perspective) to those located elsewhere in Cape Town and thus utilised geographical proximity more at a metropolitan level as opposed to the vicinity of CTIA.

Most (38%) of the establishments that utilised the services of manufacturing firms were located elsewhere in the City of Cape Town municipality, and 24% of the firms were in other provinces of the country. A small number (about 10%) of the firms that subcontracted the services were located within the environs of CTIA, while 14% of the firms that subcontracted the services of the manufacturing firms were located outside South Africa. Like the previous discussion, the findings reflect the possibility of subcontracting-related agglomeration at a metropolitan/ municipal scale.

It was also essential to analyse the backward and forward linkages of the manufacturing firms. It was uncovered that the majority (33%) of the firms sourced their inputs largely outside South Africa, and around a quarter (26%) of the firms obtained their input from areas within the City of Cape Town municipal area, 21% sourced their inputs from other provinces, and a smaller number of the firms (comprising 7%) obtained their input from the neighbouring firms located in the vicinity of CTIA. The findings show that geographical proximity was not a determinant, as most inputs were received from firms located beyond the borders of South Africa. This could explain, at least in part, the linkages between the manufacturing firms and the airport while acknowledging that the input from (or output to) other countries could be transported through road and sea-based modes of transport.

Concerning the destination of the output of the manufacturing firms, close to a quarter of the firms (24%) sent their output to other South African provinces of Gauteng and KwaZulu-Natal, and 23% of the firms located in the vicinity of the CTIA sent their products to other areas in the Western Cape province. This shows that geographical proximity was not a significant factor, as only 11% of the firms indicated that their products were delivered within the environs of CTIA. The findings on the source of input and destination of products nullify, at least in part, the argument that with respect to industries that are vertically connected through an input-output arrangement, the upstream industry is attracted to locations with a concentration of downstream firms (Venables, 1996).

5.3 Locational behaviour

More than half (55%) of the respondents of the manufacturing firms indicated that before occupying the premises used at the time of the survey, their firms were located elsewhere, implying that 45% of the firms had always been located in the vicinity of CTIA. Among the firms that were previously located elsewhere, three-quarters (75%) were once situated in other industrial sites/ business premises within the City of Cape Town municipal area, while 25% were previously located at other premises within the study area, reflecting stickiness of the environs of the airport and/ or the municipal area. The so-called stickiness denotes the ability of an area to attract and retain businesses (Markusen, 1996).

The majority (55%) of the manufacturing firms moved from their previous locations because of the inadequate space to efficiently run their business operations. For instance, some respondents noted that they did not have adequate storage facilities at their previous premises. Additionally, 10% of the representatives of the firms pointed out that they moved from the previous locations as they had secured land to develop their premises. The other 10% moved from their previous premises because they wanted their firms closer to freight distribution firms near CTIA. Another 10% of the firms explicitly indicated that they relocated to the current premises because they preferred to be close to CTIA while the remaining 10% decided on the current premises because of other factors.

Further to the centrifugal factors from the previous premises discussed above, it was important to analyse the centripetal factors that influenced the location of the manufacturing firms in the vicinity of CTIA. The majority (53%) of the firms were attracted to their premises by the centrality of the study area, and 21% of the firms highlighted the advantages of being close to the airport. About 16% of the firms reported that the study area was beneficial due to the proximity to significant transport infrastructure in terms of local, regional and national road networks. A smaller number (5%) of the firms noted that their locations were ideal as freight distribution establishments neighboured their firms. Also, the current premises had adequate space required for their daily operations. It can be commented that most of the firms decided on their locations not necessarily because of airport-related factors, but because they were primarily influenced by the centrality and accessibility of the CTIA's environs. On the background of the advantages that influenced the location of the manufacturing firms, it was also important to identify the problems in the environs of CTIA. 36% of the respondents noted that they were negatively affected by the gridlock and high rentals in the study area. 7% of the respondents indicated that the aircraft noise impacted their firms, and 7% emphasised security problems in the study area. 14% of the respondents had no disadvantages, showing contentment with the environs of CTIA.

To indirectly ascertain the extent of the reported problems of the study area, it was crucial to analyse the locations the manufacturing firms would relocate if they had to move from their premises. The majority (40%) of the firms preferred to relocate to other industrial precincts within the municipality, and 13% preferred to relocate to the neighbouring premises in the vicinity of CTIA. A staggering 33% of the firms

were completely satisfied with their locations and had no intention of relocating. 6.7% of the manufacturing firms preferred to relocate to other provinces in South Africa, and the remaining 6.7% preferred to relocate to other countries. The findings again show the stickiness of the environs of CTIA and/ or the metropolitan area as the firms preferred to move to areas within the municipality, the study area or not move at all.

6 FOUNDATION FOR A THEORETICAL FRAMEWORK

Informed by the empirical findings summarised in the previous section, the foundation for a theoretical framework analysing the spatial economic factors that influence the location of manufacturing firms in the vicinity of airports is based upon the interconnections between the concepts of space, linkages, agglomeration economies, proximity and pattern discussed in the Literature Overview section. The contribution is graphically displayed in Fig. 2 and unpacked in the following discussion. The discussion hereunder uses the term 'manufacturing airport-centric firms' to refer to manufacturing firms located near the airport.

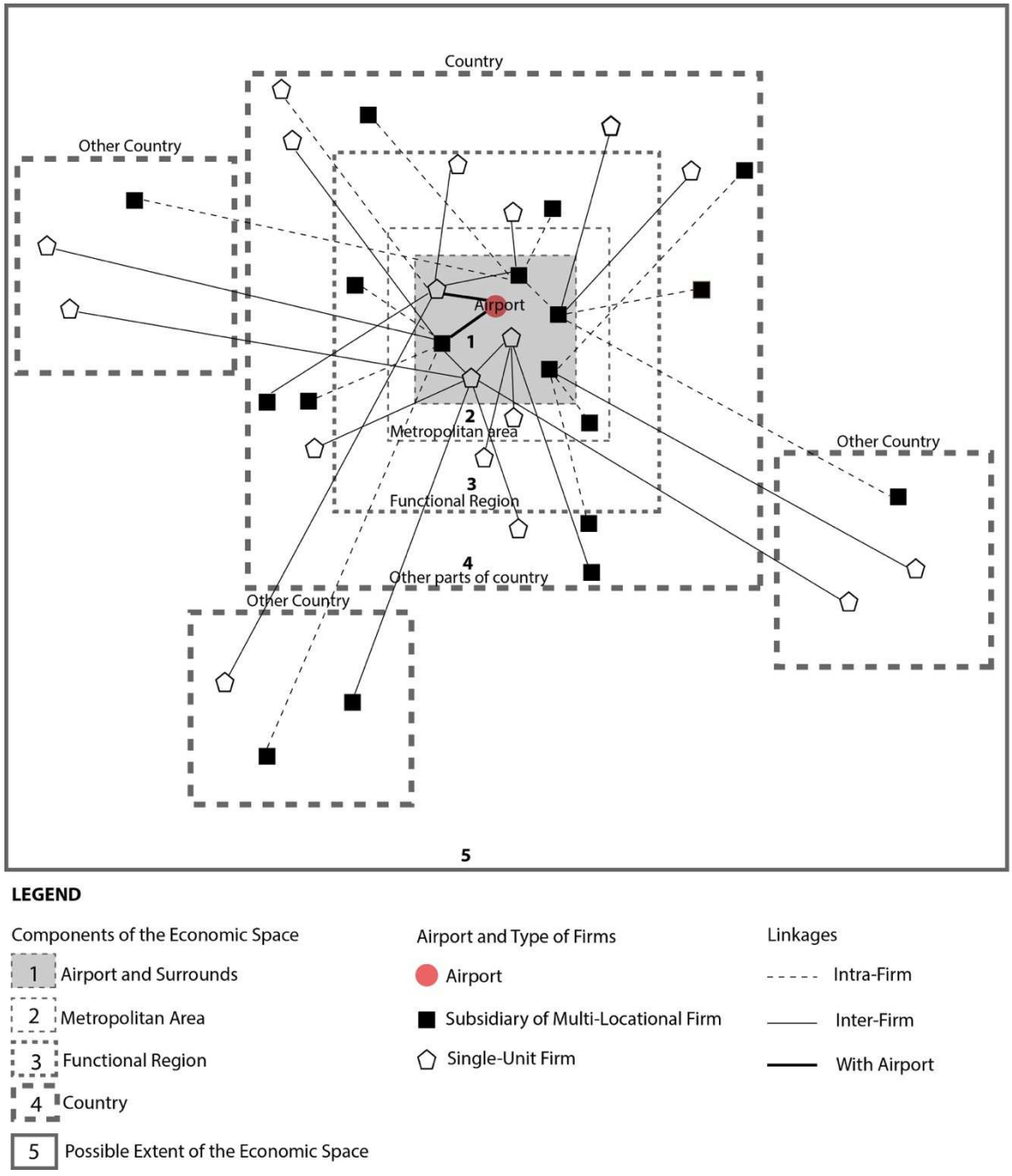

Fig. 2: A framework for manufacturing firms located in the vicinity of airports.

6.1 Immediate environs of the airport

The first component of the economic space (in Fig. 2) represents the airport and the associated manufacturing airport-centric firms, which are predominantly small establishments involved in a range of manufacturing activities. The firms choose their location for three main reasons. Firstly, the majority decide on the location because of the centrality/ accessibility of the airport and its environs. Secondly, some choose their premises to be geographically close to the airport or vie to be close to airport-related freight companies. Thirdly, some firms select their location due to the proximity to essential transport infrastructure in the form of local, regional and national road networks. These location-choice reasons show that the airport is one of the factors that directly or indirectly attract manufacturing firms. A few firms relocate from within the airport and surrounding areas over time, influenced by the search for premises that are more suitable for their particular business needs. This trend shows that the environs of the airport (as well as the broader municipal area) are sticky in attracting and retaining manufacturing firms.

Manufacturing airport-centric firms have the following attributes: one, manufacturing firms with inter-firm linkages with other firms in the geographical surrounds and/ or elsewhere; two, manufacturing firms with intra-firm linkages with units of the same firm located in the vicinity of the airport and/ or elsewhere; three, manufacturing firms that utilise a combination of intra-firm and inter-firm linkages. Although face-to-face interactions are not dominant in facilitating business, manufacturing firms have business interactions with other firms near the airport, which points to a potential spatial cluster. Most linkages are with the neighbouring transport and logistics firms, which are essential for transporting the input to the manufacturing processes and/ or shipping the finished products to markets in different economic space layers. A sizeable number of the firms also have linkages with the neighbouring manufacturing firms, pointing to the possibility of localisation economies arising from the intra-industry linkages within the airport's environs. However, regarding vertical linkages, a negligible number of manufacturing firms source their manufacturing input and/ or send their products to the neighbouring firms.

Most manufacturing airport-centric firms have linkages with the airport, utilising it for airfreight to receive raw materials/ input to the manufacturing processes and/ or shipping the finished products to the suppliers/ market. With different frequencies of utilisation, the majority of those firms use the airport at least every three weeks. The manufacturing firms that use the airport benefit from urbanisation economies by being geographically proximate to the airport and the associated airfreight services.

6.2 Municipal area

The linkages (and agglomeration economies) of manufacturing airport-centric firms are not restrained by geographical proximity to each other and the airport. The second component of the economic space (refer to Fig. 2) represents a municipal area in which the airport is situated. Relative to manufacturing airport-centric firms, firms in the broader municipal area have the following characteristics. Firstly, some firms have intra-firm linkages with manufacturing airport-centric firms, i.e. interactions between units of the same firm. Secondly, firms in the broader municipal area have inter-firm linkages with manufacturing airport-centric firms. These two categories are not mutually exclusive; hence, some of the firms near the airport have a combination of inter- and intra-firm linkages with firms located in the broader municipal area. Lastly, other firms in the municipal area do not have significant linkages with manufacturing firms in the vicinity of the airport and are, therefore, not in the same economic space.

Through vertical (buyer and seller) arrangements, airport-centric manufacturing firms source some of their manufacturing input from within the municipality and similarly send some manufactured products to areas in other parts of the municipality. Subcontracting is one of the business arrangements used to realise the inter-firm linkages between firms in the municipal area and manufacturing airport-centric firms in the following manner: firstly, manufacturing airport-centric firms use the services of firms in the broader municipal area through subcontracting; and secondly, firms in the municipal area utilise the services of manufacturing firms through subcontracting. Manufacturing airport-centric firms use these two arrangements simultaneously.

The linkages of manufacturing airport-centric firms and firms elsewhere in the metropolitan area are based on geographical proximity and organisational proximity. However, the relevance of the former is declining due to the increasing geographical distances from the airport. Manufacturing airport-centric firms' linkages (internal and external to the firm) and agglomeration include firms positioned elsewhere in the metropolitan area.

6.3 Functional region

The intra-firm and inter-firm linkages involving manufacturing airport-centric firms do not cease within the bounds of the municipal area as defined by the administrative boundaries. The third component of the economic space relates to a functional region. The distinction between the municipal area and region is not clear-cut. Because distinctive administrative boundaries do not define the region, it can be referred to as a functional region. Similar to the attributes of the metropolitan area, the region accommodates firms with the following characteristics: firstly, firms with intra-firm linkages with manufacturing airport-centric firms; and secondly, units with inter-firm linkages with manufacturing airport-centric firms. Other firms in the region do not have significant linkages with firms around the airport and, therefore, do not form a significant part of the manufacturing airport-centric firms' economic space. At this level of the economic space, subcontracting is one of the business arrangements used to achieve the inter-firm linkages between firms in the region and the manufacturing airport-centric firms. The manufacturing firms also source some of the input from the region and/ or deliver some manufactured products to parts of the region.

The influence of geographical proximity is diminishing, and the linkages are mainly based on organisational proximity. However, it should be acknowledged that because the airport is not situated at the geographical midpoint of the municipal area, there are instances where it could be geographically closer to some parts of the region than certain parts of the municipality. In this regard, geographical proximity still has a role in the operations of the manufacturing airport-centric firms' economic space with firms in the region.

Although the magnitude of linkages is declining, some firms in the region are still part of the same economic space as the manufacturing airport-centric firms regardless of the increasing geographical distance and changes in administrative boundaries.

6.4 Other parts of a country

The linkages and organisational of manufacturing airport-centric firms extend beyond the functional region. The fourth component of the economic space relates to other parts of a country. Manufacturing airport-centric firms, therefore, have linkages with firms (or units of the same firm) located in other parts of the country. Similar to firms in other components of the economic space, firms elsewhere in the country have the following linkages: one, firms that have intra-firm linkages with manufacturing airport-centric firms; two, firms with inter-firm linkages with manufacturing airport-centric firms. The inter-firm linkages are realised through, inter alia, the framework of subcontracting wherein manufacturing firms around the airport use the services of firms elsewhere in the country and/ or offer their services to firms in other parts of the country, beyond the region and province. Three, there are firms with a combination of intra-firm and inter-firm linkages with manufacturing airport-centric firms. Other firms do not have direct linkages with airport-centric firms and are, therefore, not part of the same economic space.

Specifically, manufacturing firms source their manufacturing input from other parts of the country and/ or send their finished products to markets elsewhere in the country, which could be facilitated through the airport as well as other modes of transport. At this level of the economic space, geographical proximity has no role in the operations of airport-centric manufacturing airport-centric firms. The economic space's inter-firm and intra-firm linkages and operations are based entirely on organisational proximity. Manufacturing firms around the airport are, therefore, part of the same economic space as firms in other parts of the country, regardless of the great physical distances and administrative boundaries that separate them.

6.5 Multi-country activities

Although the presence of multinational firms may be limited in the environs of the airport, the linkages of manufacturing airport-centric firms extend beyond the borders of a country, leading up to the last component of the economic space (Fig. 2). While acknowledging the relevance of other modes of transport given the diversity of the activities of the manufacturing firms; the firms utilise the airport's airfreight services to source the input (to the manufacturing processes) from other countries and to a smaller extent ship their products to markets elsewhere in the world. These vertical arrangements (to transport low-weight, high-value items) utilise organisational proximity in light of the great distances between the airport and other parts of the world.

Therefore, manufacturing firms near the airport have intra-firm and inter-firm linkages with firms in other countries. Similar to other levels of the economic space, subcontracting is one of the business arrangements

used to achieve the inter-firm linkages across national borders. The subcontracting arrangements and backward and forward linkages with firms in different parts of the world show that in the style of Perroux (1950), operations of the economic space of manufacturing firms located in the vicinity of airports can be global.

7 CONCLUSION

To extend the literature on the geographical positioning of economic activities in the vicinity of airports, the paper aimed to formulate the foundation for a theoretical framework for analysing the spatial economic factors that influence the placement of manufacturing firms in the vicinity of airports. The following closely intertwined concepts were used as building blocks: space, proximity, linkages, agglomeration economies, clustering and pattern. The resultant foundation for the empirically-informed theoretical foundation is based on five layers of the economic space: environs of the airport, broader municipal area, functional region, other parts of a country, and multi-country. Within the first (core) layer, the airport is, among others, understood to be a centre of a spatial cluster of manufacturing firms, characterised by dense intra-firm and inter-firm linkages. There are also strong linkages between the manufacturing firms and the airport, wherein the airfreight services are used to source input to the manufacturing processes and/ or transport the finished products to the markets/ buyers in different layers of the economic system. The linkages of manufacturing airport-centric firms, therefore, extend to other layers of the economic space and essentially occur within the framework of vertical (buyer and seller) arrangement and manufacturing firms that engage in subcontracting activities that are not restrained by geographical space. It is hoped that the elementary contribution would sensitise policymakers, planners and authorities to the spatial economic dynamics of manufacturing firms positioned in the vicinity of airports. Furthermore, it is intended that the contribution be improved upon and be employed to conceptually guide future research on the spatial economic factors that influence the location of manufacturing firms in the environs of airports.

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Functional Integration of Rural Communities with Propulsive Urban Growth Centre in their Vicinity through Nature Base Solutions

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1 ABSTRACT

Haridwar, being a religious town with 18 most visited famous temples, about 34 quintals of flowers are supplied daily for religious offerings. Given the constant demand for temple flowers in the sacred city of Haridwar, there is an opportunity to cultivate them within the nearby villages and supply them to temples and flower sellers. Once used in temples, these flowers can be reused for extraction of essence and essential oil, making incense stick, natural colors and compost and production of bioenergy. This approach not only proves economically viable but also aligns with environmental sustainability, creating livelihoods in a harmonious manner.

The present paper identifies these growth drivers by combining functional demand of Urban area (Haridwar City) and functional supply of Rural areas (Gaindikhata Rural Cluster). A unique Self-sustaining Circular Economy Ecosystems (SCEE) is created through the functional linkages of Haridwar's urban areas and Gaindikhata's rural areas. The paper discusses the Rural-Urban Circular functional linkages approach which not only generates employment but also streamlines complex processes for a more efficient system. The paper analyses the potential of floriculture in combination with other potential value-added functions such as medicinal, aromatic products as well as bio- energy. The existing paper promotes the functional integration between rural communities and nearby urban growth centers through nature-based solutions to foster sustainable development, improve quality of life, and address environmental challenges.

After understanding the sustainable practices for both rural and urban populations, the present paper promotes creating of skilled workforce that can contribute to eco-friendly initiatives, identifies the development of small-scale enterprises in rural areas, such as recycling units, agro-processing units and ayurvedic medicinal units creating economic opportunities for both Rural-Urban local communities. By implementing these nature-based solutions, the paper created a more holistic and sustainable integration between rural communities and nearby urban growth centers, ensuring the well-being of both environments and their residents.

Keywords: functional linkages, circular economy, sustainable development, linking rural-urban economy, rural-urban functional integration

2 INTRODUCTION

India with many religions, floral offerings are common in all the religious ceremonies and festivities. Therefore, India, being a spiriual country has vast potential in floriculture sector. In this sector Marigold flower possesses vital role in various auspicious ceremonies and temples. In these occasions flowers are discarded after single use and considered to be sacrosanct so that they canont be disposed with other waste for decomposition. Moreover, there is no proper handling strategies for this waste. This huge amount of flower waste of religious places contain high organic content resulting in a very slow decomposition process (Jadhav et al, 2013) and, therefore, creates air, water and land pollution. With increasing numbers of visitors in the religious places the requirement of the flowers and consequently the generation of enormous number of waste has increased (Samadhiya et al., 2017). To date disposal of temple flowers in most of the holy cities of India is a major challenge (Padmavathiamma et al., 2008; Murthy, and Naidu.2012; Wani et al., 2013).

Haridwar, one of the most visited pilgrim towns with 18 most visited famous temples, requires about 34 quintals of flowers for its daily religious offerings (Author, Primary Survey 2022). Marigold is the common

flower for this purpose. Due to lack of proper disposal nearly 90% of the flower offerings are found as flower debris lied in the city as unattended waste and dumped into the river Ganges as well. With constant demand of flowers for the temples in the sacred city of Haridwar, there is a requirement to cultivate them within the nearby villages for the supply to temples and flower sellers and there is an urgent need to manage this huge amount of floral waste sustainably.

3 ACTION RESEARCH AREA: GAINDIKHATA CLUSTER

Gaindikhata Cluster, located in Bahadrabad Block of Uttarakhand is 25 kms away from Haridwar towards Nazimabad on NH 74 (Figure 1). This cluster contains 7 Gram Panchayats comprising of 25 villages, with geographical area of 19268.70 Hect. The total population of the cluster is 58109 persons (during 2022) with 10565 number of households. The cluster represents typical characteristics of physical and geographical setting, like plain, undulating terrain, hills and mountain topography; micro-climatic variation, good forest cover under the shadow of big urban centre, i.e. Haridwar City.

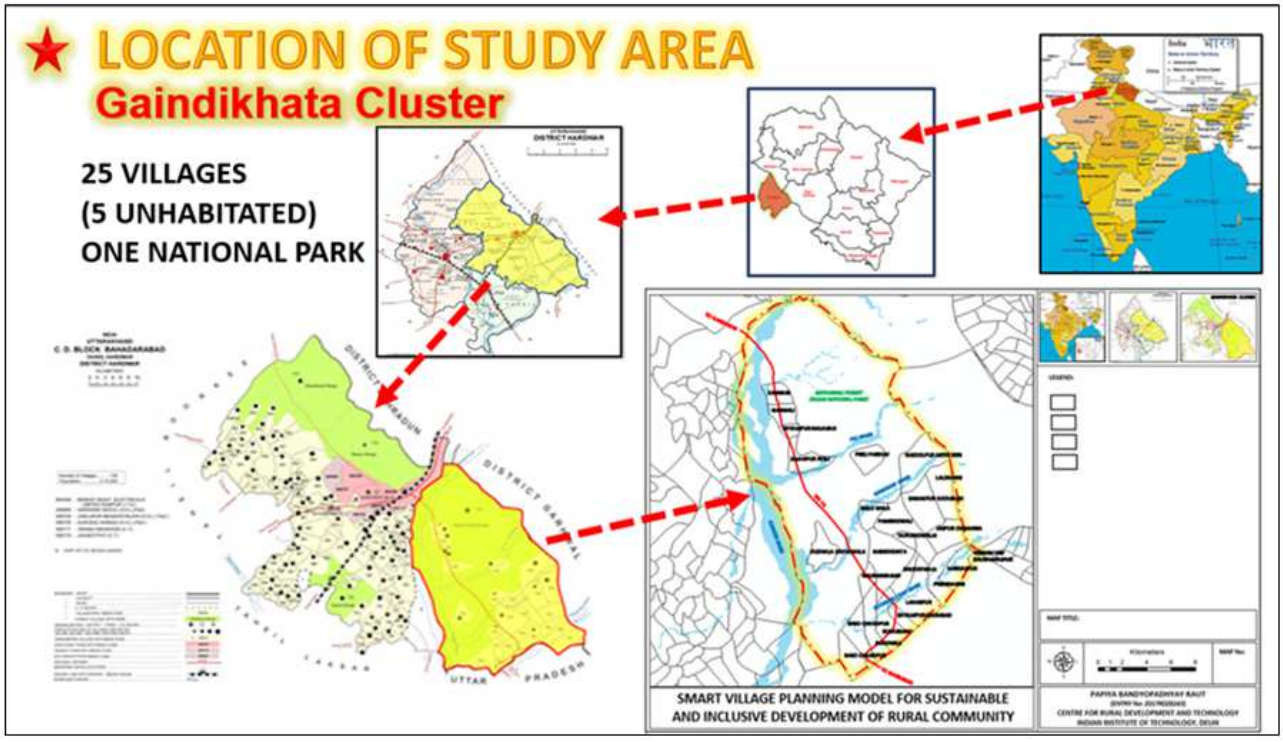


Fig 1: Location of Action Research Area: Gadikahata Cluster

Gaindikhata Cluster dominated by on farm (i.e. agriculture) as main activity and so the mainstay of the economy but at subsistence level. The present paper is an action research to increase the quality of life by enhancing the economic opportunities and diversification of economy by introducing the concept of Self-sustaining Circular Economy Ecosystems (SCEE) (Figure 5) by creating the functional linkages between Haridwar, as an urban area, and, Gaindikhata cluster as rural areas. Though the present action research explored many SCEEs related to medicinal plan cultivation, horticulture, sericulture, animal husbandry, small scale handicraft industries, village base tourism and eco-tourism, agro-forestry, food base industries etc, for this present paper SCEE of floriculture has been discussed. Hence, the present paper analyses the potential of floriculture in combination with other potential value-added functions such as medicinal and aromatic products as well as bio- energy. The existing paper promotes the functional integration between Gaindikhata Cluster's rural communities and nearby Haridwar urban growth center through nature-based solutions to foster sustainable development, improve quality of life, and address environmental challenges.

At present Floriculture, mainly Marigold cultivation is found in only four villages, i.e. Kangri (0.58 Hect.), Gajiwali (3.51 Hect.), Sajanpur Peeli (2.87 Hect.) and Shyampur Nauabad (1.33 Hect.) villages covering net 8.29 Hect. which is 0.31 percent of total agriculture area in the cluster. With increasing demand of Marigold in Haridwar this area is experiencing a continuous trend of expansion under Marigold cultivation. As per the analysis for identification of potential areas (91.24 Hect.), it is proposed to increase the Marigold cultivation area during the year 2024 as 306.20 Hect. which is 11.54 percent of total existing agricultural area with

estimated production of 138.42 quintal per day per Hect. The existing production of Marigold in the cluster is 3.65 quintal per day per Hect (Table 1)

Sr. No.	Village Name	Existing Marigold Flower cultivation Area (2024)	Potential Areas (2024)	Proposed Area (2024)	Annual Production (in quintal)	Production per day (in quintal)
1	Gajiwali	3.51		3.51	579.15	1.59
2	Hardaspur		12.82	12.82	2114.48	5.79
3	Kangari	0.58	1.13	208.39	34384.35	94.20
4	Lahadpur		30.21	30.21	4983.91	13.65
5	Padmowali		47.08	47.08	7768.98	21.28
6	Sajanpur Peeli	2.87		2.87	473.55	1.30
7	Shyampur Nauabad	1.33		1.33	219.45	0.60
	Total	**8.29**	**91.24**	**306.21**	**50523.86**	**138.42**

Table 1: Village wise Per Day Proposed Production of Marigold Flowers during 2024 (area in Hectare). Sources: Primary Survey by Authors, 2022.

4 CONCEPT OF CIRCULAR ECONOMY THROUGH FUNCTIONAL INTEGRATION BETWEEN RURAL HINTERLAND AND URBAN AREAS.

The huge amount of flower waste causing air, water and soil pollution is a challenge for the Municipality. It is required to have a proper and ecofriendly process for disposal and management of flower waste. The flowers which are being dumped, several value-added products can be prepared from these. It can be used for making value added products like incense stick and herbal colors, natural dyes, medicine, decorative items, handmade paper, food production, pigments, biofuels, compost, bioethanol (Bhattacharya et al., 2012; Ranjitha et al., 2014; Waghmode et al., 2016). As it contains enough nutrient and lignocellulosic material, it can be used for bioenergy and biofuel production to achieve sustainable energy demands. Basically, Environment friendly methods can be adopted to manage and treat this floral waste in a cost -effective way to develop useful products on sustainable manner (Bundela, et al., 2010; Jain et al., 2016). All these nature base solutions will enhance the job opportunity in the rural hinterland of the cluster through the functional integration with Haridwar urban center.

Government of India has launched Horticultur Mission for North East and Himalayan (HMNEH) States. This programme provides funds for promotion of floriculture though demonstration of technology and technological deployment, production of quality planting material, organic farming, efficient water management and plant health. Formation of Self-help group (SHG) at village level, managing funds from HMNEH, capacity building of the SHGs of Gaindikhata Cluster will integrate the functionality between the rural communities and Haridwar urban centre leading to promote nature base solution to address circular economy and environmental challenges of flower waste disposal.

Fig 2: PRA with local community

5 METHODOLOGY ADOPTED

In order to have first-hand information Participatory Rural Appraisal (PRA) technique has been conducted with different resource groups of Kangri, Sajanpur Peeli, Gajiwali, Peelipadav, Jaspur Chamaria, Samaspur Katabarh and Tapadowali villages (Figure 2 &3). Existing Resource Mapping, Seasonality Chart of the marigold production, Land-use mapping, problem tree analysis and problem matrix analysis were taken up with classified group of respondents of these villages. Simultaneously, actual field measurement to appreciate the ground conditions and to bridge the information gap has also been taken up. In this course of action both the qualitative and the quantitative data have been collected to supplement each other and to have the complete picture of the action research area.

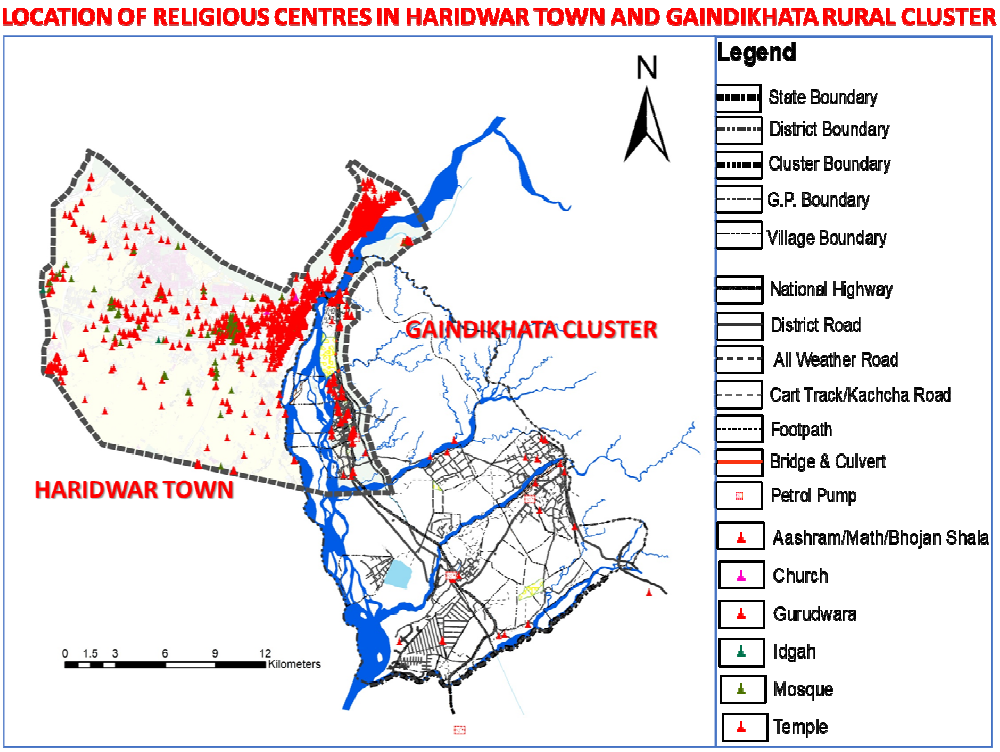
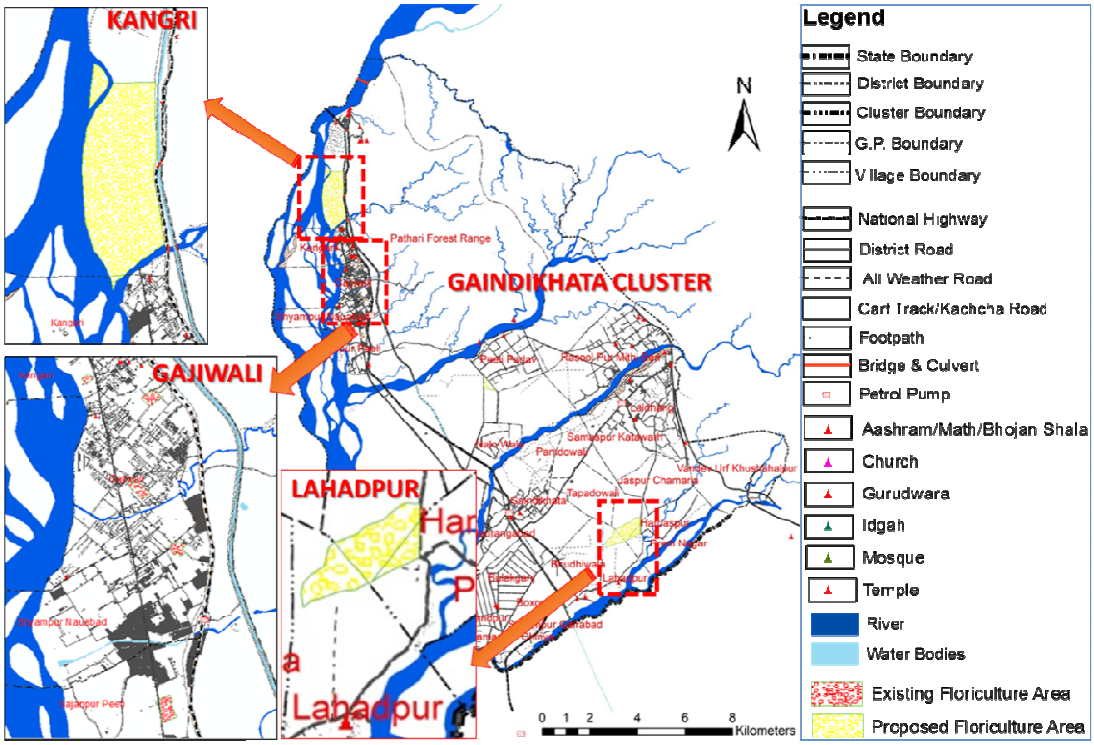


Fig 3: Location of Religious Centres in Haridwar town and Gaindikhata Rural Cluster



6 POST HARVEST VALUE ADDED PRODUCTS OF MARIGOLD

6.1 Incense Stick Production from Marigold Waste (Value-added Products)

In most of the Indian households lighting Incense sticks, Agarbatti and Dhoop symbolizing the religious practice of worship. The CSIR – CIMAC (Council of Scientific and Industrial Research – Central Institute Medicinal and Aromatic Plans) Lucknow has taken up a project ”Sakshma” which utilizes an innovative technology using flowers waste and leaves for incense sticks production. This innovative technology significantly addressed the associated problems of toxicity of smoke generated from typical charcoal -based incense sticks by using a massive amount of dried floral waste. In this technology the marigold waste is dried and mixed with binding agents (gums and makko powder) along with a small amount of charcoal to make it combustible. It has been able to reduce the poisonous smoke and harmful gases and help in combustion. It is found that 1500 Incense sticks could be made from 1 kg or raw material (Sakshama). Thus, Marigold can be utilized to prepare economical commercial product, providing job opportunity with low to no side effects. Bhoksa Basti of Jaspur Chamaria is selected for this incense dhup, agarbati making. Bhoksa community women of Jaspur Chamaria have already formed several Self-Help Groups (SHG). One hand roll incense stick making unit to collect 300 kg of flower waste from Haridwar to produce 4,50,000 incense sticks with 150 manpower, which can be marketed to Haridwar. Hence, three units are proposed in Gaindikhata Cluster, one unit each in Samaspur Katabarh, Jaspur Chamaria and Tapadowali villages. Out of total marigold flower waste which is 3094 Kg, 900 Kg of waste can be used in these three incense stick units providing employment to 450 households. Department of Horticulture and Horticulture Mission for North East and Himalayan States (HMNEH) will provide funds for training and capacity building, skill updation,. SHG formation and required fund arrangements.

6.2 Marigold Essential Oil and Herbal Medicines (Medicinal and Cosmetics Products)

In the flavor and fragrance industries the demand for marigold is rising. The extraction of flavonoids from marigolds can be used as anti-inflammatory, antioxidant properties. The marigold petal contains high level of lutein content. These petals are significant therapeutic products for herbal medicines. Marigold oil produces strong aromatic oil which is called Tagetes oil, generally used in cosmetics and perfume industry. This oil as an antiseptic can also be used to relieve sunburn, warts, itching, acne, sores dry skins. Therefore, it develops as a resource and exhibits great potential for contributing circular bio -economy. One extraction unit of Essential Oil is proposed at Kangri village with the total production of 81.54 Kg per day from 10,442 kgs of fresh marigold flowers per day which further can be marketed at Haridwar. Farmer can earn profit of Rs 80,000/- after spending of Rs 10,000/- per hectare each year (Figure 4).

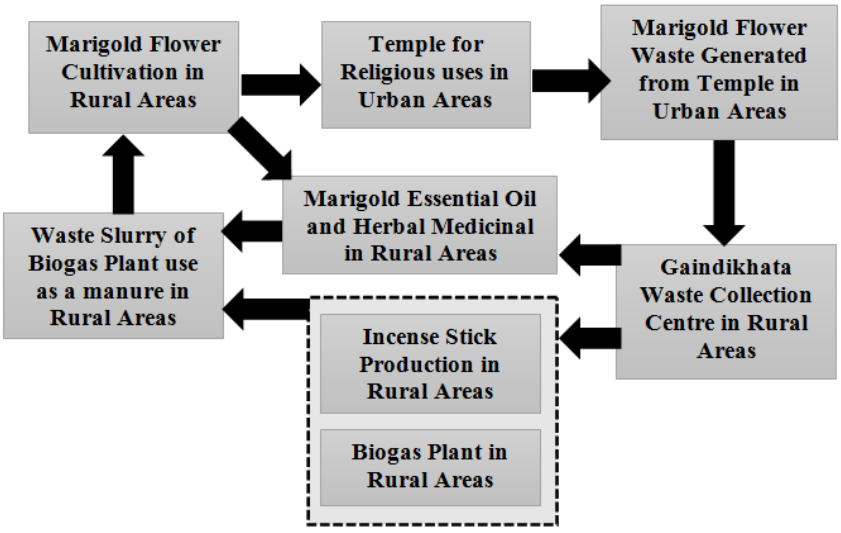
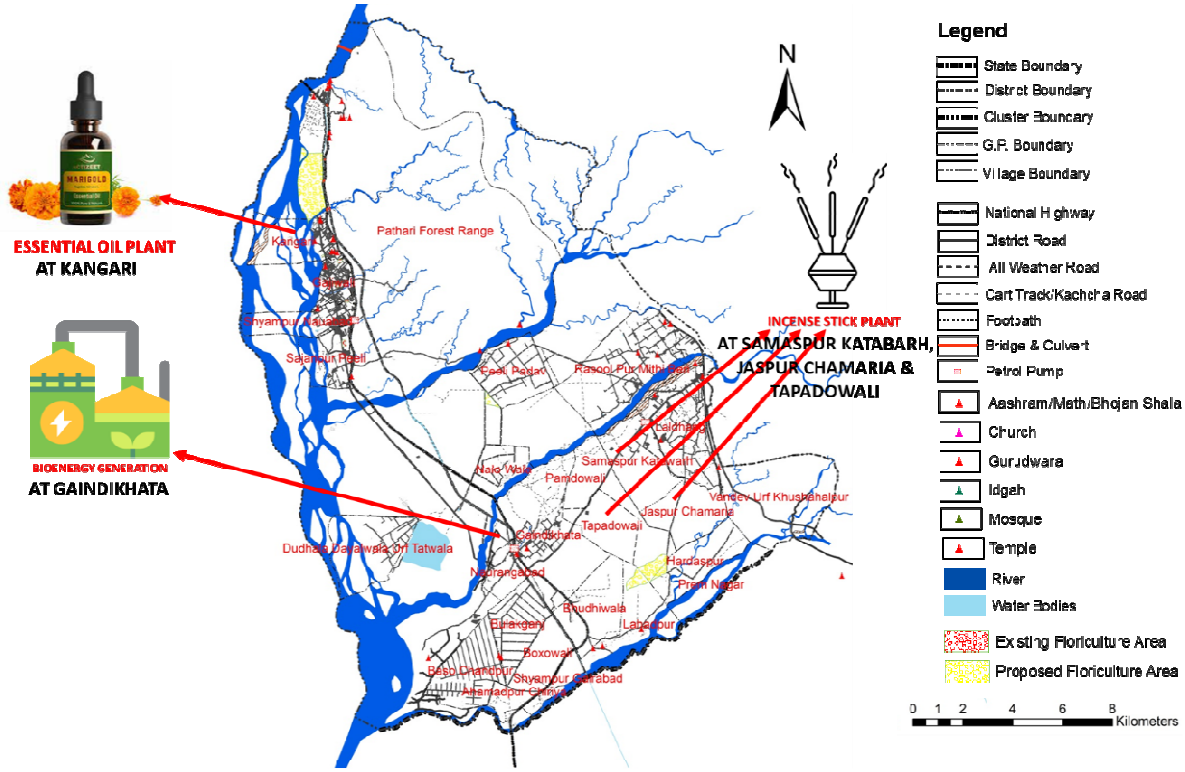


Fig 5: Example of Self-Sustaining Circular Economy Ecosystems (SCEE)

Oil extraction scheme can be formulated as individual entrepreneurship or a group of individual or company or as SHG to handle this agro –based enterprise. Department of Horticulture and Jila Yojna will provide the necessary funds and training for setting up the extraction unit under Growth Centre Scheme.

6.3 Bioenergy Generation through Marigold Flower Waste

Flower waste by using anaerobic digestion technology can be used as raw material to produce biogas (Lakshmi and Vijayalakshmi, 2017). A potent greenhouse gas is Methane (Singh and Bajpai, 2011). The huge amount of temple flower waste can be used for biogas production. It will reduce emission of methane in the atmosphere and soil pollution from decomposition of flower waste (Rashed and Torii, 2015). Moreover, the energy requirement for cooking purpose will also be met. The biogas produced from flower waste can be used as a source of heat for cooking purposes or can be used in electricity production (Kulkarni and Chane Gaonkar 2019). The amount of biogas to be produced from one kg of marigold flower waste is 120.46 liters per day. (Shrastha, Chaulagain and Shrastha, 2017). Hence, with the waste of 2194 kg it is estimated that 264289 liters of Biogas can be produced per day which can support about 117 households in Gandikhata village. This eco-friendly approach will reduce the carbon footprint. The waste generated from Biogas plant will be used as manure in cultivation areas. The Unnat Bharat Abhiyan (UVA) under Indian Institute of Technology, Delhi will take up the initiative for proving tangible infrastructure and knowledge dissemination for fostering awareness (Figure 6).



7 CONCLUSION

The action research-based paper tries to attempt to develop Self-sustaining Circular Economy Ecosystems (SCEE) by creating the functional linkages between Haridwar as an urban centre and Gaindikhata cluster as rural hinterland through enhancing the economic opportunities and diversification of economy through nature-based solution. After understanding the sustainable functional practices for both rural and urban communities, the present paper promotes circular economy that can contribute to eco-friendly initiatives, identifies the development of small-scale enterprises in rural areas, such as recycling labour incentive incense sticks units, essential oil extraction units, further use of essential oil for ayurvedic medicinal units and bioenergy generation units creating circular economic opportunities for both Rural-Urban local communities. By implementing these nature-based solutions, the paper created a more holistic and sustainable integration between rural communities and nearby urban growth centers, ensuring the well-being of both environments and their residents.

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GreenTwin: Developing a Digital Twin for Sustainable Cooperative Mobility and Logistics in Rural Areas

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1 ABSTRACT

Public transportation is often poorly developed, especially in rural areas, which leads to an increased dependence on personal vehicles. Moreover, since transportation is one of the main drivers of climate change, our research project aims to explore cost-effective methods for sustainable last-mile logistics in rural areas and support decision-makers utilizing a dashboard. For this purpose, an open marketplace platform is planned that intelligently networks suppliers and service providers in a region and bundles orders and deliveries. The aim is also to motivate customers and users to behave in a more environmentally friendly way by suggesting appropriate offers through the way they are presented on the marketplace. This is achieved by integrating Digital Twin (DT) technologies, cognitive agent-based social simulation, transport management systems and recommendation systems. To ensure the project aligns with public needs and acceptance of proposed approaches, we conduct census-representative surveys alongside the development and experimentation phases. In this paper, the overall structure of the research project and the submodels underpinning our solution are introduced. It also includes a visual mockup of a rural region's DT and introduces several use cases.

Keywords: smart mobility, rural development, sustainability, planning, digital twin

2 INTRODUCTION

One main driver of climate change is transportation, which is responsible for approximately 25% of worldwide CO_2 emissions (Masson-Delmotte et al., 2022). This issue is particularly acute in rural areas, where reliance on private vehicles is high due to limited public transport and grocery store access (Süddeutsche Zeitung, 2022). Furthermore, rural areas in Germany usually have a higher proportion of commuters between and within its districts and go through more extreme demographic changes (Dauth & Haller, 2018), which makes the problem more prominent in the areas. Although alternative logistics approaches for the last-mile aiming at reducing costs or CO_2 emissions already exist (cf. Ranieri et al., 2018; Halldorsson and Wehner, 2020; Hepp, 2018; Frehe et al., 2017), most of those are not customised to rural areas or do not include concepts of heterogeneous products and groceries, which, for example, require compliance with cold chains.

Therefore, to alleviate this issue, our research project GreenTwin aims to explore cost-effective methods for sustainable last-mile logistics of various goods particularly in rural areas by considering unique regional characteristics (e.g., infrastructure and demographics) and needs of the inhabitants (e.g., dependency on private vehicles and long travel time). Additionally, it proposes a dashboard that displays information concerning the effects of different approaches to support stakeholders to make decisions. With the methods identified as effective, we expect the findings on mechanisms on promoting pro-environmental behaviours, strengthening regional businesses, and increasing the life quality of residents in the area.

This paper is structured as follows: Section 3 discusses the aims of the research projects as well as the methodology used. Section 4 presents the general structure of the research project consisting of several project phases and subsequently elaborates on these introducing the submodels underpinning our solution, required data as well as techniques for data acquisition. Furthermore, this Section includes a visual mockup of the solution, and the research projects use cases. Finally, Section 5 provides concluding remarks and an outlook on the next steps along with future work.

3 A TOOL FOR PLANNING SUSTAINABLE LOGISTICS IN RURAL AREAS

To address the issues mentioned in Section 1, our research project aims to provide an innovative solution that

(1) uses different optimisation techniques for minimizing greenhouse gas (GHG) emissions at the last-mile in logistic tours on a general level while considering the needs of actors involved (e.g., inhabitants and stakeholders);

(2) considers additional constraints that are incorporated by models of users via a cognitive social simulation;

(3) includes a novel marketplace concept and a model that captures links between sub services, end users and additional actors in a graph model, to enable a transparent and optimised end to end connection of sub services into one service for the end user that also displays the effects of connecting services.

One of the core tasks of this project is the development of a research demonstrator: the Digital Twin (DT) of the rural area. Additionally, we intend to place (physical or virtual) containers in the focus region that, among other services, provide goods for everyday use to decrease the need for running errands between communities. This would enable us to both pre-plan experiments consisting of scenarios and interventions within a simulation environment (DT) and to display it on a demonstrator for stakeholders in order to facilitate their decision-making and evaluate the findings, making use of the container setting in cooperation with regional partners. Evaluating the findings will provide local partners with a decent base for starting logistic cooperations. For instance, the containers are placed to minimise the necessity of traveling between different districts in the region for errands. The DT is thus planned to provide real-time ecological balance calculations for the optimization of various services and service chains. The outcome of such an evaluation of approaches is then shared with decision-makers using a dashboard. Within the framework of DT, agent-based modelling (ABM) as well as psychological and sociological theories are employed to represent both individual and regional characteristics at a more detailed level. ABM is especially useful when it comes to simulating heterogeneous population under certain circumstances as it is well-suited for illustrating a complex decision-making of individuals at micro level and resulting behaviour dynamics of the population at macro level (Smith and Rand, 2018).

Using a marketplace individuals can book orders from (regional) retailers by making a digital contract. Here, customers should be able to choose between different retailers based on various key indicators, for example,

regionality, energy efficiency and price. Furthermore, transportation of the agents, especially when it comes to deliveries, is planned, and optimised using a transport management system within the DT. We aim to link combinatorial optimisation methods for logistics services (e.g., Multi-Commodity Flow Optimisation (Dziubany et al., 2020a)), agent-based (distributed) optimisation and heuristical optimisation methods as well as AI approaches (Maiorov et al, 2019; Stolfi and Alba, 2018; Mohammed et al., 2019). The goal is to develop AI-supported optimisation processes that align with both the overarching objective of minimization of GHG emissions and the individual, heterogeneous goals of users. This involves continual incorporation of the region and population's constraints, facilitated by integration with the DT. When first introducing new technologies or solutions, it is often a lengthy process that includes social skepticism (Lermer et al., 2015; Renn and Beninghaus, 2013), although advantages of those solutions are recognised by users (e.g., convenience, safety, costs, social participation, and environmental benefits (Lidynia et al., 2021)). Skepticism arises from, e.g., insufficient knowledge (Kyriakidis et al., 2015), concerns about dealing with data/privacy (Schomakers et al., 2018) or a missing inclusion of target users (Zaunbrecher and Ziefle, 2016). Hence, it is important to conduct research on the inhabitants' acceptance of potential services and their demand using census-representative surveys and interviews with other stakeholders and on how the acceptance rate can be increased in the best-case scenario. Additionally, the resulting data is used in the DT to model respective attributes of individual agents.

The outcome of this research comprises a dashboard designed for decision-makers to evaluate the impact of sustainable logistics concepts in rural areas. The dashboard provides real-time eco-balance calculations, offering a comprehensive view of the environmental impact of logistics operations. This functionality is crucial for decision-makers striving to balance ecological considerations with logistical efficiency. Our approach incorporates the diverse needs of both individual users and the broader population. By considering these heterogeneous demands, our optimisation processes could ensure a more tailored and inclusive solution for sustainable logistics in rural regions.

4 PROJECT STRUCTURE AND MODULES

Our research project consists of different phases, each dealing with specific tasks for the development process (see Figure 1).

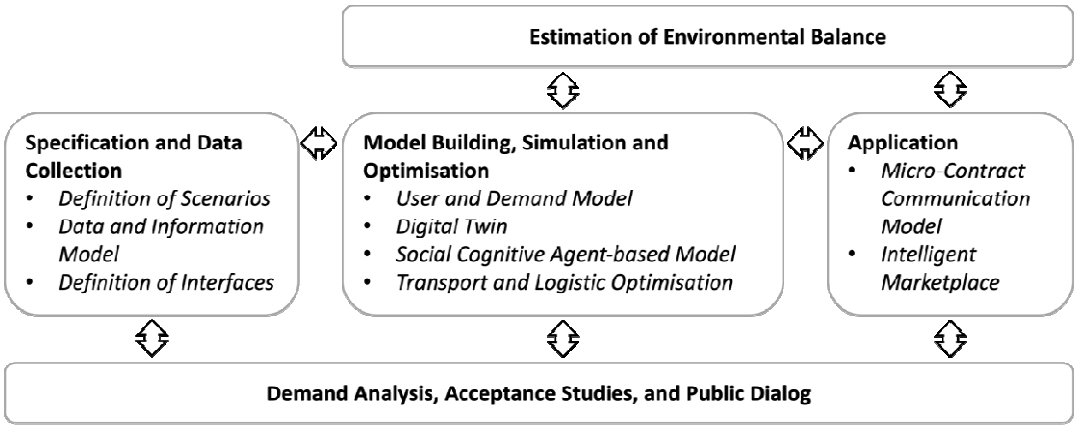

Fig. 1: Phases in GreenTwin

Each subsection of this Section focuses on one of these phases and presents details on the utilised methods. The Model Building, Simulation and Optimisation phase, which is further elaborated on in Section 4.1 summarises the submodels that are created from integrating DT technologies, cognitive agent-based social simulation, as well as network modelling and optimisation systems. The submodels are applied in an intelligent marketplace whose goal is to connect retailers, service providers and consumers of the region in the Application phase, which is discussed in Section 4.2. Scenarios concerning methods for sustainable last-mile logistics, the definition of interfaces between the models and required data are provided in the Specification and Data Collection phase. This phase is presented in Section 4.3. During modelling and application, we evaluate the different approaches based on GHG savings (Estimation of Environmental Balance), which is described in Section 4.4. To ensure the project aligns with public needs and acceptance of proposed approaches, we conduct census-representative surveys during the whole development process

(Demand Analysis, Acceptance Studies, and Public Dialog). These are introduced in Section 4.5. Additionally, Section 4.6. presents the visual mockup of the demonstrator of our solution consisting of a dashboard and different views of the marketplace solution.

4.1 Model Building, Simulation and Optimisation

User and demand model To effectively capture behavioural patterns of the rural model regions, it is crucial to base the user model and demand predictions on empirical data to ensure they are not only based on theoretical considerations but also on a regional understanding of the area and its social, economic and logistical processes. Therefore, this research project employs method triangulation, combining various types of empirical data for a comprehensive understanding (Baur & Blasius, 2019).

Conducted studies focus on the current state of people's mobility-, environment-, and shopping-related habits, which are critical aspects for the proposed application scenarios. Further, the research delves into the influence of social environments on decision-making. This aspect recognises that broader social dynamics often shape individual choices, adjusting personal behaviour to its societal context.

The methods employed include interviews, which serve to gauge stakeholder perceptions. The insights are validated through broader census representative online surveys to capture a wider population's viewpoints. Simultaneously, the local rural community is surveyed to explore region-specific prerequisites and behaviours. This part of the research provides insights into the community's current mobility and shopping habits and their attitudes towards environmentally friendly practices. The local perspective is vital for tailoring solutions and predictions to the community's unique context.

Finally, the design of all empirical endeavours is underpinned by psychological theories, including the Theory of Planned Behavior (TPB), Social Exchange Theory (SET), Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM), and the Unified Theory of Acceptance and Use of Technologies (UTAUT) (Ajzen, 1991; Davis, 1985; Emerson, 1972; Fishbein and Ajzen, 1977; Venkatesh, Thong, and Xu, 2016). These theories have been widely applied to explain engagement in sharing and collaborative consumption (Barnes and Mattson, 2017; Boateng, Kosiba, and Okoe, 2019), acceptance of last-mile delivery (Kapser and Abdelrahman, 2020; Hinzmann and Bogatzki, 2020), and mobility on demand (Ye, Zheng, and Yi, 2020; Nordhoff et al., 2021) – even though they mostly focus on an urban setting and the rural context remains underrepresented in the current research landscape. These theories guide the interpretation of the data and provide a structured framework for the entire research process, connecting the empirical findings to broader theoretical constructs.

Digital Twin and Social cognitive Agent-based model For testing different scenarios and interventions, a DT is used as a virtual representation that reflects the situational characteristics and individual decisions in the corresponding region in order to support decision-makers (cf. Wang et al., 2023). Since we focus on rural areas in Germany, we consider distinctive characteristics that set them apart from more densely populated or urban areas. First, rural areas in Germany usually consist of multiple small communities, which often have a poorly developed public transport infrastructure. Moreover, these rural areas are characterised by demographic changes, such as rural migration, including extraordinarily high numbers of commuters (Dauth and Haller, 2018). The existing body of literature concerning DTs of inhabited areas predominantly concentrates on urban environments, there arises a necessity for a model that considers the unique characteristics of rural areas, addressing this gap in research (Rodermund et al., 2024).

In GreenTwin we develop a multi-layer DT framework that enables experimenting with various scenarios and intervention approaches promoting pro-environmental behaviours among rural areas' inhabitants. In each layer of the framework, we address one essential factor required for representing such areas and the complex interplay between these decision-relevant factors. For instance, the region, infrastructure, and its specifics are modelled in a spatial layer, the inhabitants of the region as well as people commuting within and between communities are included in the individual layer. Because we aim at integrating the influence of the social network (e.g., neighbours, family, and friends) on individual decisions, we additionally include a social layer for the region's DT.

The spatial layer builds the foundation for the individual decisions made in the DT as it determines the individual's options by defining the situational circumstances. Here, private as well as public areas (e.g.,

households, neighbourhoods, workplaces, and places of interest (POIs) like supermarkets) are located. The communities' infrastructure, consisting of streets and public transport, connects these individual locations.

To represent people of interest in the individual layer we make use of Agent-based modelling (ABM) and Multi-agent systems (MAS), as these methods have established themselves in representing complex cognitive decision-making (Bonabeau, 2002; An, 2012). Additionally, we employ psychological theories explaining factors relevant in the decision-making for or against pro-environmental behaviours. To adequately incorporate those theories in an agent architecture we make use of the Belief-Desire-Intention (BDI) model (Bratman, 1987). BDI organises individual goals (desires), information (beliefs) and action-oriented measures (intentions) into mental states, whereas in a deliberation process intentions are derived from beliefs and desires (see, e.g., Bratman, 1987; Berndt et al., 2018). The spatial and individual layer are linked by the social layer. This layer is particularly important for our use case because the communication within social networks plays a crucial role in shaping pro-environmental behaviour (see, e.g., relevance of social norms (Cialdini and Jacobson, 2021), or social learning (Chwialkowska, 2019; Zhang et al., 2021) or even in the diffusion of information and new technological solutions (Rogers et al., 2014). The inclusion of such concepts and theories as social norms and social learning into MAS leads to Agent-based Social Simulation (ABSS) (Davidsson, 2002). ABSS is highly suited for representing interactions between individual agents under consideration of social concepts and it ultimately enables us to conduct experiments concerning different scenarios while taking both psychological and social aspects into account (Squazzoni et al., 2014).

To verify assumptions made in the process of conceptualizing and modeling there is a variety of data sources utilized. For instance, in the spatial layer we combine OpenStreetMap[1] (OSM) data and census data[2] to create the physical environment as well as the initial population. The individual layer requires data from empirical studies to model daily schedules as well as the agent's decision process. Furthermore, to determine actual places the agent travels to for work, necessary and leisure activities, statistical data (e.g., Pendleratlas[3] (Commuter atlas) or Datenreport Umwelt, Energie und Mobilität (Data report environment, energy, and mobility) (Brockjan et al., 2021)) is used. For the social layer, additionally to the data retrieved from the spatial layer, we also make use of empirical data. The empirical studies that are to be conceited in this project are further discussed in Section 4.5. For validation we intend to use publicly available data (statistics, that have been introduced before, e.g., commuter statistics, OSM or census data) as well as traffic count data from the respective rural region. Additionally, an extract of the empirical study data is employed for this purpose, too.

Transport and Logistic optimisation In the area of transport and logistics optimisation, the focus is on optimising the structure of logistics networks (i.e., the selection of suitable hub locations), the consolidation of transport requirements and the actual execution of the resulting transport shipments.

When it comes to passenger transport, aspects such as customer decisions must also be taken into account when optimising a service. Short-notice bookings or cancellations in particular can mean that a mobility service is no longer economically viable. Here, flexibility and convenience for customers must be balanced with efficiency and thus the cost-effectiveness of the service. Preliminary work already exists in this area that deals with the use of flexible time windows for the planning of passenger transportation. Here it was investigated how users can be offered shared rides within time windows of maximum size, while at the same time maintaining the flexibility and profitability of the system (Dziubany et al., 2020b). A Mobility on Demand service places even higher demands on optimisation, as online optimisation is required to adjust vehicle routes in near real time. Various approaches exist for this, including queuing theory (Iglesias et al., 2019), simulation-based approaches (Tilg et al., 2020) and multi-commodity flow problems (Stenberg et al., 2021). In this context, we plan to research optimisation methods that enable an online solution for on-demand mobility and also take into account rebookings and cancellations while maintaining the profitability of the overall system. The integration of heterogeneous players, such as private and commercial drivers, and networking with public transport services should yield the system to be highly flexible. Preliminary work has

[1] https://www.openstreetmap.de/
[2] https://ergebnisse2011.zensus2022.de/datenbank/online/
[3] https://www.pendleratlas.de/

already been carried out on the integration of private and commercial mobility services. The study by Gu et al., 2024 examines algorithms that optimise matches between drivers and passengers based on their time constraints. It also minimises travel time and operating costs while integrating public transport with cars and ride sharing services. Such Mobility as a Service (MaaS) platforms are becoming more and more widespread. In their work, (Cruz et al. 2020) analyse typical challenges of such platforms and how they use sharing concepts for maximum flexibility. They also present various business models that can emerge in this environment.

To this end, existing algorithms of the PSIglobal software application are being further developed for use in passenger transport and last-mile logistics. Furthermore, detailed emission tariff functions are generated and parametrised to be able to carry out optimisation calculations not only based on costs, but also with regards to sustainability (GHG emissions). Finally, possibilities are to be created to be able to interactively adapt an already modelled logistics network during operation at short notice so that the effects on essential KPIs (e.g., costs / GHG emissions, resource utilization, pick-up and delivery time windows, ...) are recognizable.

In addition, an event-based model of mobility and logistics processes is being developed in the project so that manual scheduling of transport orders is possible in addition to automatic scheduling.

4.2 Application

The newly developed services are to be made available via an open marketplace platform. “Open” means, that both private customers and providers as well as commercial providers can use the platform to purchase or offer products and services. The marketplace platform is connected to the DT and uses optimisation and recommendation algorithms to display suitable offers to users. The individual services are not treated isolated, as the marketplace is expected to have a network effect. The central platform instead of separate platforms should increase the likelihood that users will use several of the services on offer. In addition, some aspects of the scenarios considered are interdependent in terms of environmental effects or logistics. By taking a holistic view through simulation and evaluation, the DT can represent the region in a more accurate way. Offers are supposed to be tailored in a way that they have a positive effect on the overall system, considering logistics, emissions, market situation and personal preferences. In order to make this process transparent and to encourage users to decide based on these aspects, metrics such as CO2 balance or personal saving opportunities should be openly displayed. Regardless, users will also be able to actively search for other offers and services and select them. Figure 2 displays the overall structure of the marketplace platform and its interfaces to the systems around it. The DT covers various scenarios, including product delivery service, share economy and mobility on demand, and could also use third-party data via interfaces, including markets and mobility service providers. Those scenarios addressed here are introduced in more detail in Section 4.3. The information from the DT is incorporated into the marketplace in order to regulate it, for example by creating new offers or adapting existing ones, or by displaying more suitable offers to users first. Users access the offers of the marketplace via a contract framework, which is described below.

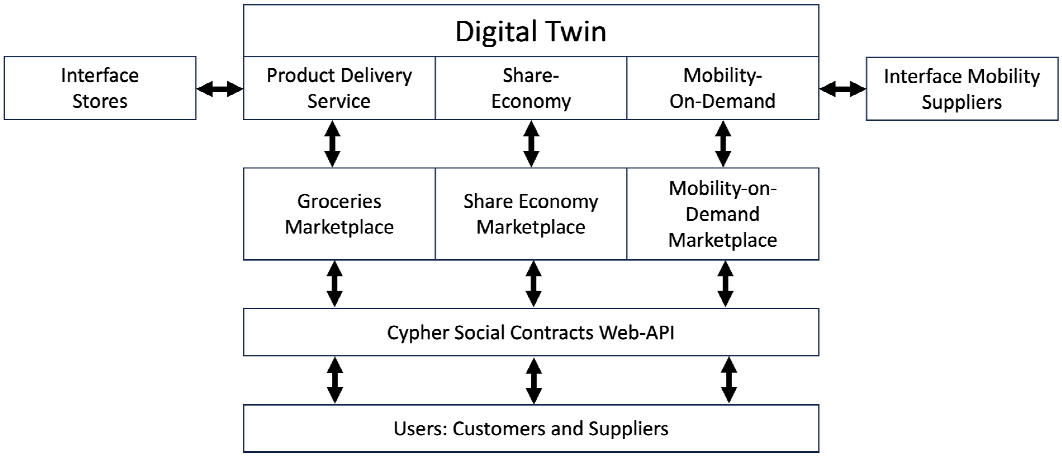

Fig. 2: Structure of the Marketplace Platform

The various offers and services on the marketplace require communication between the parties involved. For this purpose, an open source framework for cypher social contracts is going to be used (Creutz et al., 2021).

The framework enables generic digital contracts between two parties that can be written in natural language. The contracts are private through strong encryption and forward-secrecy and are automatable and can therefore also be used for contracts between humans and machines or machines only. In contrast to many other smart contract protocols, this system does not require blockchain or similar technology. This makes the system extremely energy-efficient and allows it to run on IoT hardware and even be used over limited bandwidth channels, such as LoRaWAN via a middleware (Creutz et al., 2022). A legal audit by the University of Frankfurt also confirmed that the contracts concluded using this framework can be legally valid (Spiecker et al., 2023). Contracts are derived from templates that specify the structure of a contract, i.e., the contractual steps included and the responsibilities of the parties for each step. A contract can then be seen as an instance of such a template. During this project, the described contract framework is to be integrated into the intelligent marketplace and forms the backbone of the marketplace's communication infrastructure. In summary, the use of this micro-contract system enables a private, secure, and legally binding method of carrying out transactions on the intelligent marketplace.

4.3 Specification and Data Collection

In the realm of DT technology, the significance of both the quantity and quality of data cannot be overstated, particularly in the context of developing agents and models integral to its framework. The efficacy of ML algorithms, a cornerstone in the functionality of DTs, is heavily influenced by the dataset's volume. This emphasises the need for a careful specification of the scenarios, aiming to define the required data sources that are crucial for the investigation. Such a strategic approach facilitates the establishment of a comprehensive data management concept, encompassing data structure organization, tailored explicitly to the objectives inherent to each specified scenario. This methodology ensures a robust foundation for the operational efficiency of DTs, thereby enhancing their reliability and applicability in simulating and optimising real-world processes. Even though the DT and marketplace are intended to cover the entire spectrum of last-mile logistics and mobility in the future, in our research and implementation, to cope with the enormous complexity of our designed application, we are focusing on four representative example scenarios. These example scenarios are to be fully implemented within the first version of the project and tested and evaluated in pilot operations. The scenarios were chosen to cover as many aspects of future use cases as possible and thus enable a representative study of the overall project. Specifically, this pertains to the domains of the sharing economy, demand-driven product management, logistics planning for delivery services, and a scenario involving mobility on demand, all of which is explained in more detail in the following.

Share Economy: Many households have a range of expensive items that are only used rarely or for limited periods of time. These include, for example, various types of tools such as drills, saws or lawnmowers, or sports and leisure equipment such as kayaks or camping equipment. These are just a few examples that clearly show that there are items that should be shared with others rather than owned, to save resources both economically and environmentally. The underlying idea is, that both private and commercial providers (e.g. DIY stores) can offer such items for hire. The items can then be rented out via a booking system that is integrated into the marketplace. They are stored in intelligent networked lockers located in the local hubs close to the customers. This system is supported by the DT, which maps demand and distributes the goods to the hubs via an intelligently controlled delivery fleet. From a systems perspective, a DT of the population is needed for several purposes. It serves to determine the demand of a community and, based on that, to develop a recommendation engine integrated into the marketplace. This offers customers, for example, renting as an alternative to purchasing products. Additionally, an intelligent fleet management system is required that distributes goods and shares resources with other services, such as food delivery, to be more efficient.

Demand-driven product management: Many supermarkets align their product range nationwide which leads to food waste. Local supply, in contrast, offers the opportunity to tailor product ranges very precisely to actual needs. By understanding the preferences of the specific target group and aligning the product ranges accordingly, food waste can be reduced. At the same time, the need to travel to distant stores for certain products can be counteracted to a certain extent and the reliance on private vehicles for basic supply can be reduced as well. This requires the DT to learn and map the local target group, e.g., inhabitants of a village,

along with their needs. By sharing knowledge across several local models, incentives for new products can also be derived. For example, a new product can be introduced in a smart hub for testing, because it has performed well in other smart hubs with a similar target group. On the system side, local models could be developed. This could make the use of federated learning in this scenario beneficial.

Planning of delivery services: An open marketplace platform and an optimised shared delivery service could break the monopoly of large online marketplaces, such as Amazon or wholesale chains in favor of local providers. Thanks to the DT, the online marketplace can learn the needs and preferences of individual customers. In based on customer purchase behaviour, representing customer preferences and capable of being integrated with additional local models. This way, purchases from different retailers can be bundled and delivered together. The delivery fleet could be a combination of professional delivery services and takeaway services, e.g. by integrating commuters. Deliveries could also be bundled by delivering to smart hubs, which should be particularly convenient for customers with busy schedules, similar to DHL lockers. Deliveries could also be made to the front door, for example for elderly or people with mobility impairments. What is needed here, is an agent-based DT for granular mapping of needs and preferences at customer level, which can be ensured by using the marketplace. In addition, route planning in conjunction with intelligent fleet management, that can handle heterogenous fleets, consisting of delivery networks and private people, is required.

Mobility on Demand: In the rural model regions, public transport coverage is not developed well enough to provide a viable alternative to private vehicles. The time intervals between services are too long and, due to the many scattered villages, the journey times are also too long. For reasons of time and flexibility, most people therefore rely on private vehicles. This poses a problem for older people or people with disabilities, as well as people with limited financial resources, and impairs their quality of life. A highly flexible and affordable mobility service could provide a remedy here. A system for booking journeys integrated into the marketplace is indended to be combined with intelligent route planning. Private individuals can also be involved as drivers. A service as such should not compete with public transport but should complement it in a reasonable way. On the system side, the DT helps to anticipate requests and bundle journeys. Journeys should be bookable both in advance and at short notice. This requires advanced optimisation processes that can also respond to last-minute requests and cancellations while remaining profitable.

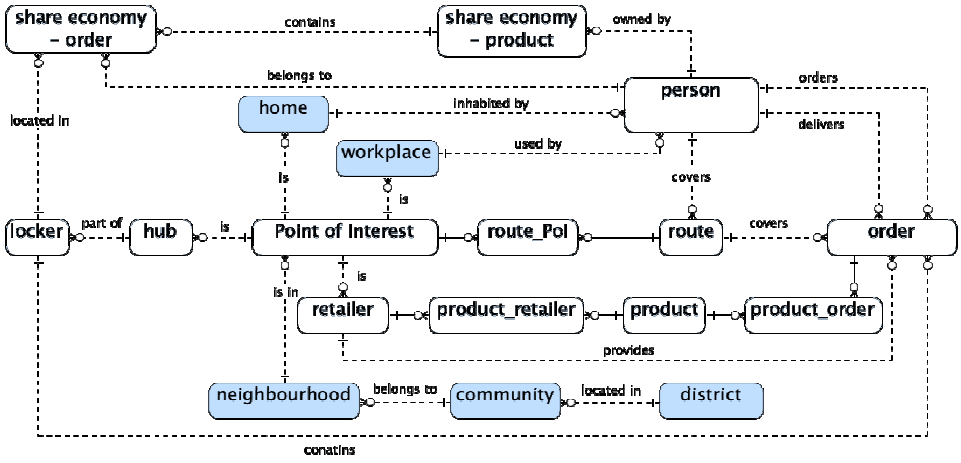

Fig. 3: GreenTwin Cross-Scenario Database Schema

Each of the previously defined scenarios contains components that must work together, but at the same time place different demands on the database. For this reason, a system is being developed that links different data structures with each other. This means that only data relevant to the respective task of a component is processed to ensure maximum efficiency and resource conservation. However, the scenarios can also benefit from data recorded in other scenarios. Our approach is to implement a system that connects the marketplace platform with a database and a knowledge graph (see 4.2). The simplified database schema is shown in Figure 3. It contains information about people and their routes, products, providers, and hubs. The marketplace platform is the interface to the users and accesses the database. Interactions such as inquiries or offers lead to the information within the data structures being modified and, if necessary, expanded. If, for example, a user inquiry is made on the marketplace platform, this is transmitted as a query to the knowledge graph, which contains personal information and preferences as well as product and supplier information. The

response then contains offers individually tailored to the user. The connections, weightings and attributes within the knowledge graph are changed by user decisions and thus continuously improved. The amount of data increases with each user interaction, which leads to a larger amount of training and therefore also to an improvement in the algorithms.

4.4 Estimation of Environmental Balance

The conception of the DT is predicated on enhancing real-time environmental impact evaluations within the logistics domain, encompassing the distribution of goods and regional service provisions. Its mechanism includes integrating environmental assessments into optimisation algorithms and elevating the ecological impact to a critical parameter within these computational processes. This integration makes a decisive contribution to supporting the introduction of sustainable logistics methods that meet the increasing demands for environmental compatibility. A key innovation in this area, our research project, is designed to help the consumer decision-making process by providing transparent insights into the environmental impact of different services. Such transparency is expected to create a market with increased sensitivity to sustainability issues. The underlying AI model will be designed to ensure flexibility across various logistical configurations and its applicability and effectiveness. The project provides for a review mechanism to underline the scientific integrity of the environmental assessments. This step is essential to drive a paradigm shift towards sustainable logistics and service models. This will contribute to the discourse on developing a DT for sustainable cooperative mobility and logistics in rural areas and provide a novel approach to mitigating environmental impacts through technological innovation and scientific validation.

4.5 Demand Analysis, Acceptance Studies, and Public Dialog

Innovations usually face skepticism, especially if they are not well communicated or seem to be solely based on developers' and/or specialists' ideas (Gulari et al., 2011). Many studies have shown, however, that the involvement of the intended users as early as the development can help facilitate a better product, in the sense of usability, and also a smoother roll-out (Rohracher, 2005). In rural regions, technology awareness, roll-out, and attitude differ from those of city dwellers (Porru et al., 2019). Therefore, a crucial part of this project is the involvement of the public who are the target users.

Thus, the first step after thinking of a possible solution for a more sustainable and environmentally friendly way to ensure supply in rural regions of Germany, is to conduct a demand analysis. What is missing and what, specifically, do citizens wish was improved. That way not only does one a) get to know the target group but also b) their needs and demands. While the first part (a) also facilitates a blueprint for the DT, the second part (b) can help to understand acceptance or rejection of the innovation.

In most cases, acceptance studies are based on acceptance models, especially established technology acceptance models such as TAM (Davis, 1985) or UTAUT (Venkatesh et al., 2016). They survey different variables to understand why people would want to use a technology (e.g. Turner et al, 2010). In case of AI and mobility, those acceptance models have to be extended as, for example, trust has not been a traditional part but was shown to be a strong predictor (Brell et al., 2019). Other context-relevant aspects need to be included to understand if and to what extent they influence the acceptance and willingness to use and participate in the innovation.

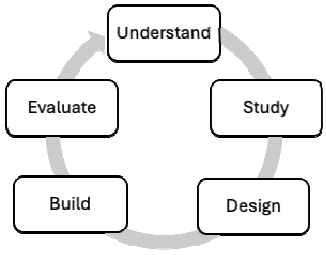

Fig. 4: Structure of the Empirical Research Approach

It is important to include the public early on and use different methods to do so, from demand analysis (what do people need, want, and expect), to acceptance studies (what factors influence the projected willingness to

use the technology/innovation and perhaps change habitual behaviours), to finally communicate and offer transparency of the ideas, methods, and outcome or results of the use of the proposed innovation. This iterative approach and design cycle (see Figure 4) has been shown to be very valuable to successful research and development (c.f. Courage, C & Baxter, 2005; Harper et al., 2008).

4.6 Dashboard: Visualising Pro-Environmental Behaviour

As mentioned in Section 3, one outcome of this research project is the provision of a dashboard that supports decision-makers by means of comparative analysis of different scenarios and interventions in terms of various relevant key indicators. Additionally, our marketplace solution connects users (end customer) and providers by placing tailored offers as well as tracking and visualising personal reduction in CO2 emissions. Figure 5 shows those different views:

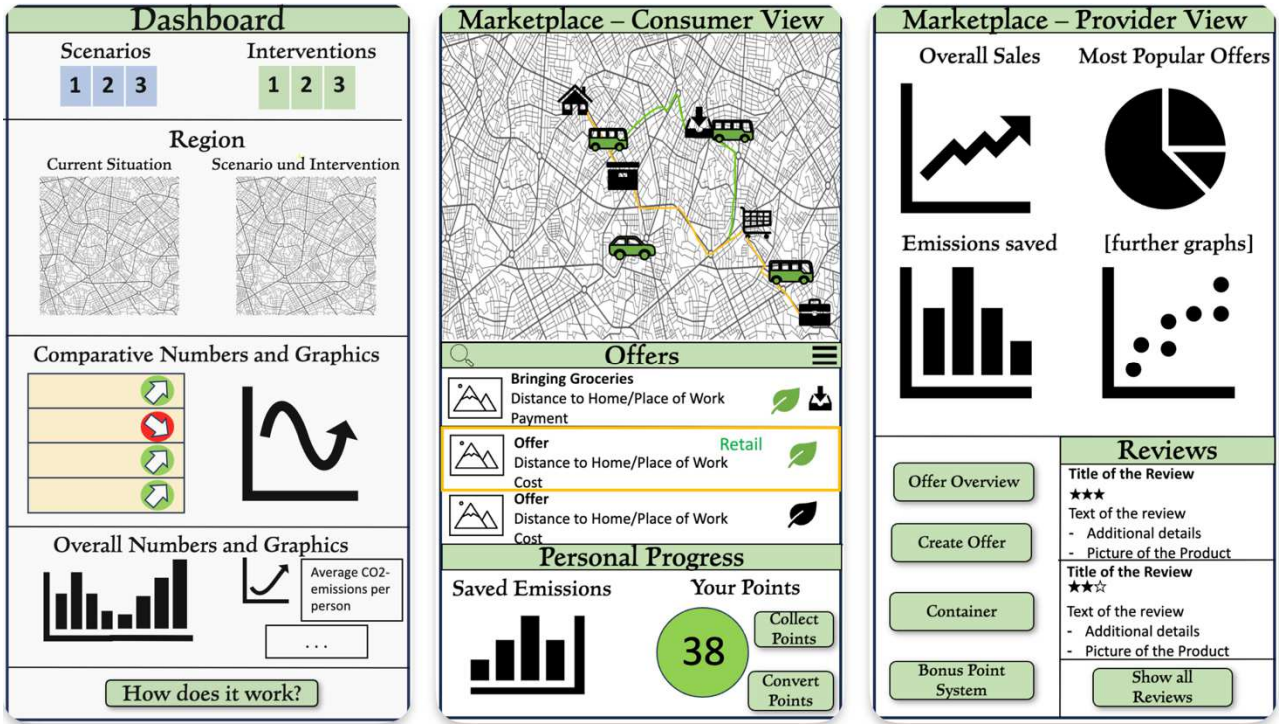

Fig. 5: Visual Mockup of Dashboard (a), Consumer View of Marketplace (b), and Provider View of Marketplace (c).

(a) The Dashboard interface is segmented into five sections. Users have the option to select from a variety of scenarios and interventions for evaluation, which are then visually represented. The second section presents dual map views of a specific region; the left map displays the region in its current state without any interventions, while the right map illustrates the region post-intervention application. Enhanced visual elements, such as color-coded districts/routes/communities, will be utilised to represent the key metric: CO2 emissions. The third and fourth sections offer a comparison of variable changes between the two maps and display relevant indicators for the region post-intervention. The final section is designed to provide users with a detailed explanation of the dashboard's functionality and the underlying DT technology.

(b) The Consumer View of the Marketplace summarises information relevant for customers. It facilitates the placement and acceptance of offers among neighbours or local providers. The map view can be used to show them the most environmentally friendly routes to take for each task, as well as nearby alternatives to travel such as public transportation. Users can add their home address and place of work to the map, to further calculate best routes. Routes are color-coded, with green indicating the most sustainable option and yellow representing the user's regular travel path. The map also marks local stores and Shared Economy containers. Users can pick offers and services based on environmental impact and can collect points by choosing options with less CO2 emissions than an average alternative. Those offers are marked with a green leaf, whereas offers that would not lead to any saving of emissions are marked with a black leaf. If possible, participating providers could offer users to exchange these points for rewards at their stores.

(c) Providers themselves have an overview on the benefits of the project for themselves, such as sales data and CO2 emission reductions. Additional options might be to create a new offer, show an overview of

current offers and manage a bonus point system and show reviews of previous customers. They can further access the container-system, which allows for a Share Economy System, as introduced in Section 4.1.

5 SUMMARY

In this paper, we introduced the GreenTwin project which aims to explore methods for sustainable last-mile logistics in rural areas that benefit both residents and other stakeholders by improving local supply and supporting logistic decisions that are cost-efficient as well as environmentally friendly. For this, we combine agent-based simulation, cognitive modelling of the population, and optimising logistics processes as primary methodologies. This paper outlined the project's development phases and discussed the submodules and used methods as well as how these are combined to an overall solution. Since this research project is still ongoing, whereby some challenges must be acknowledged. For instance, our solution requires merging of data from various data sources with different granularity to mirror the real-world rural region in our (sub) models. Hence, we plan on maintaining a collaborative data concept to control information flow between the submodels. Furthermore, as it is challenging to adequately prepare information on effects of different logistics services to provide a robust and transparent basis for decision-makers future work thus includes the design and development of visual components and relevant information in dialogue with stakeholders (e.g., through workshops or studies/surveys). Lastly, in this research project we aim at providing a solution as a pilot demonstrator to prove the applicability of the overall solution in a model region. Hence, this project may therefore be followed by the further development of the solution into a prototype in the target region and extensive testing under real conditions.

6 ACKNOWLEDGEMENTS

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Investigating the Research Landscape of Virtual Reality in Built Environment Education on the African Continent: a Bibliometric Review

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1 ABSTRACT

The Fourth Industrial Revolution brought disruptive changes that profoundly impacted all industries, promising revolutionary progress in ideologies and processes. Although this revolution casts a shadow of uncertainty, it brings great potential to improve how humanity will live, learn, work, and play in the future. Industry 4.0, like previous revolutions, significantly impacts the often-sluggish Construction Industry and, equally, the education of future construction professionals. Disruptions by technologies such as Building Information Modelling (BIM), Virtual Reality (VR), Augmented Reality (AR), 3D Printing, Artificial Intelligence (AI) in various automated derivatives and other technologies have shown a significant impact on the design and creation of the Built Environment (BE). Consequently, education and training in Industry 4.0 systems are crucial for smooth progress in articulating the development of future professionals. In this research, the authors investigate the research landscape of virtual reality and BE education in an African context. An appropriately curated bibliometric review process is utilised to examine the current trends in this niche body of knowledge. The review process utilises exported data from Scopus using the terms 'virtual reality', 'education', 'built environment' and 'Africa' between 1998 and 2024. The exported data was then analysed using Vos Viewer software to illustrate the main keywords around the study area through network maps. Preliminary results reveal that VR technology in BE education is severely under-researched in Africa and globally. However, a steady incline in VR technology research reveals an increase of 719.73%. With due consideration of the importance of VR in an educational setting, the lack of research reveals not only an under-researched field but also an underutilised resource that has the potential to be incredibly impactful. Therefore, a recommendation is made to conduct empirical studies in educational settings using VR technology as part of the pedagogical approach to training future BE professionals.

Keywords: 4IR, biuilt environment, virtual reality, pedagogy, Africa

2 INTRODUCTION

The progress of humanity is a testament to the remarkable ingenuity of our species. Human beings have an inherent ability to progress rapidly and, at the same time, consciously reflect and implement corrective actions for their perceived benefits. At various historical moments, human beings have left evidence of their development. The unravelling of history between the Stone Age and the Modern era illustrates the humanitarian progress that had sudden peaks of rapid development. A critical peak in development that marks the modern era is recorded as the move from an agrarian society to an industrial mass production model, which trades globally rather than locally. Although the first industrial revolution is a reminder of the tragedies committed in Africa, the rapid development of human beings is well documented, consequently leaving the world unrecognisable over a short period (Oliver & Oliver, 2017; Christopher, 2023).

Humanity actively participates in the fourth industrial revolution, which has recently become a pivotal topic in various knowledge bodies. The rapid development of artificial intelligence and machine learning and a firm reliance on digital technologies to advance everyday processes are keyframes of significant change. Unlike other industrial revolutions, the Fourth has impacted human processes beyond physical tasks, challenging human intelligence and bridging the gap between the biological mind and machine (Schwab, 2016; Marwala, 2021; Mazibuko-Makena & Kraemer-Mbula, 2021). This sudden change has threatened various industries, removing the need for humans in specific processes. For example, tasks that require higher-order thinking to complete will be challenging to replace compared to functions that require simple or

routine outputs (Dahlin, 2019; Webb, 2019). Consequently, this argument has been a point of heated discussion on the purpose of humans and our developmental trajectory as active citizens in the economy.

Although the rapid change in the job market is seen as a challenge, Marwala (2021) asserts that the growth of future economies relies heavily on the lifelong learning of citizens who are resilient to an actively changing environment. Continual improvement and upskilling concretise humans‘ importance in the industrial process. Johannessen (2023) states that human competence in digital technologies is the key to augmenting old competence into skills required for the labour market 4.0. In this sense, high competency in these digital technology skills becomes the currency of the future in the rapidly changing capitalist world. Although arguments are on either end of the spectrum, an agreement is that this revolution is significantly disruptive and requires human capital to embrace change.

Drawing from the premise of 4IR technology as an assistive principle in humanitarian processes and the need for upskilling, the authors use this rationale to explore technologies critical to developing future BE professionals. Furthermore, as a note, the BE industries are often categorised as digitally adverse (Abioye et al., 2021) and sluggish or resistant to change (Letsoko & Pillay, 2019). It is, therefore, a crucial departure point to explore the various 4IR digital technologies and the relevant usages within the BE. For the scope of this study, the authors focus on exploring the research landscape of Virtual Reality Technologies within the BE disciplines, explicitly focusing on implementation within the BE education sector in Africa. This approach is curated as a step in exploring a field lacking research output and potentially contains gaps in knowledge which will require further investigation.

3 REVIEW OF LITERATURE

The literature review for this study aims to reinforce the rationale, support the investigation of the research question, and locate the study's variables within the existing body of knowledge. Critical to this approach, the authors curate a review of the literature to unpack the concept of Virtual Reality and explore the perceived benefits of the technology within BE education.

3.1 Virtual Reality

Virtual Reality (VR) technology has been introduced previously; however, it was used before mass digitisation and the advent of the 4IR. Slater (2018:433) professes that contemporary VR technology has a 30-year development history and “did not suddenly appear out of nowhere in 2012”. The technology dates back to 1916 when the first head-mounted periscope was patented by Albert B. Pratt (Sherman & Craig, 2018). As early as 1931, the first flight simulators were developed and patented by Edward Link, using simple mechanical technologies to simulate flight virtually (Paro, Hersh & Bulsara, 2022). Although VR is conceptualised as a visual technology, it encompasses all senses to create immersion. In the 1950s, Martin Heilig, the father of virtual reality, experimented with multi-sensory experiences that engaged all the senses (Kapoor & Kalia, 2023). The technology was further developed by Ivan Sutherland in the 1960s using a head-mounted display (HMD) named Sword of Damocles, contemporarily known as a VR headset (Wohlgenannt, Simons & Stieglitz, 2020). At this point, most developments in VR were for professional and industrial uses. In the early 1990s, attention was turned to computer gaming used by companies such as W-Industries, Attari, Nintendo, Sega, and others (Sherman & Craig, 2018). From here on, the trajectory of VR technology changed to commercialisation and civilian uses. The years leading up to the current technologies were developmental, and the introduction of other supporting technologies now allows VR technology to be used for various purposes (Sherman & Craig, 2018; Slater, 2018; Wohlgenannt, Simons & Stieglitz, 2020; Paro, Hersh & Bulsara, 2022; Kapoor & Kalia, 2023).

Notwithstanding the digital age, eighteenth-century philosopher Immanuel Kant coined the term Virtual Reality to describe the reality in one‘s mind (LaValle, 2023). In this sense, reality was virtual (mind) and was separate from the physical world. Jaron Lanier later coined Virtual Reality, placing it in a modern setting by including digital technology as a complexity layer. Henceforth, the authors refer to the Lanier term as a basis for defining Virtual Reality. Many modern understandings of Virtual Reality tend to focus on visual perceptions; however, the Heilig approach of multi-sensory immersion is a robust benchmark from which the premise of the technology shows the potential power and abilities to simulate the real world. Zhang & Xue (2023) observe that VR technology utilises image processing and other hardware technologies to allow a sensory experience through sight, smell, sound and touch. Lv (2020) argues that although visual, auditory,

and tactile senses are well developed, researchers must do more work to create true immersion to develop olfactory, taste and mechanical perception in VR systems. By using techniques to replicate the natural world through the senses, users of VR technology can be completely immersed in the Virtual Environment (VE), which may result in an indistinguishable experience.

Beyond sense immersion, VR technology requires five key elements: Participants, Creators, Virtual world, Immersion, and Interaction (Sherman & Craig, 2018). For any VR system to work, it requires a participant to engage with the virtual environment. Various examples of this application define distinct participants and creators, such as in sports (Neumann et al., 2018), education (Radianti et al., 2020), arts (Zhang & Xue, 2023), medicine (Rantamaa et al., 2023), and several others. Creating a virtual environment that elevates the participant experience is critical to successful interdependence. With it, the perceived experience is likely to stay strong. VR technology focuses on creating a world that either mimics the physical world (captured) or creates a world using computer-generated graphics (synthetic), often termed the virtual world or virtual environment (LaValle, 2023). Therefore, prioritising the development of a virtual environment is crucial to guarantee a successful outcome.

The virtual environment must be immersive to engage a participant fully, simulating or elevating a natural experience. A study conducted by Zhang & Xue (2023) on the use of VR technology in museums to simulate a visit shows evidence of enhancing user experience by creating digital maps of exhibitions to navigate through large spaces and better interaction in a dynamic environment as opposed to standing in a static position and overall greater experience without the distraction of large crowds. Geraets et al. (2021) acknowledge the potential power of VR technology in psychological cases, where patients experience the same or better results through immersion in treatment practices and outcomes; moreover, this approach was more cost-effective, and the reach was greater. Although these are only two examples, the body of knowledge comprises several studies illustrating robust use cases where immersion through VR technologies has significantly impacted respective cases.

Interactivity, the fifth key element in VR technology, elevates the user experience to simulate the real world entirely. Sherman & Craig (2018:12) profess that the simulation must respond to user actions for VR technology to seem authentic. An experimental study conducted by Lyu et al. (2023) presents a case in which multi-sensory stimuli incorporated into virtual reality to experience an outdoor space increased the sense of immersion and presence, uplifting the interaction between human-built environments. Methodologies such as those proposed by Lyu et al. are critical, especially in the construction industry, where environmental design conditions can be simulated to assist designers in providing pre-tested solutions before implementation. Thus, VR technology shows incredible promise as a source of experimentation to enhance final implementable solutions.

3.2 VR in the Built Environment

As a base, the physical Built Environment is often used as a virtual environment to create immersion for the participant. However, the Built Environment can be created virtually for several different requirements. Virtual reality can inherently mimic real-world situations and opens the stage for experimentation before implementation (Sherman & Craig, 2018; LaValle, 2023). In this sense, Built Environmental professionals can use this tool to enhance their primary duties by adding a layer of complexity in the form of big data and Virtual Reality in their processes.

The design disciplines in the context of the Bult Environment have always relied on visual methodologies to represent, experiment, and execute projects in the grandest of scales. For example, architects and planners often use physical models to represent large urban spaces, individual buildings and even minute details. The introduction of CAD and BIM enhanced these methodologies by creating digital models of existing and future developments (Pillay, Gumbo & Musonda, 2019). Although these technologies have proven robust, the lack of immersion and interaction with space and environmental conditions has been an age-old issue; VR technology bridges this gap and offers an additional medium of experiencing space before it is physically constructed (Davila Delgado et al., 2020).

As a point of departure, the professional disciplines of architecture, planning and engineering are perceived to benefit significantly from VR technology as an assistive layer for problem-solving in the design process and a medium of representation. Beyond the prospects of a medium of representation, VR technology can be used to simulate real-world- buildings with various levels of outcomes, resulting in buildings that meet or

surpass the requirements of sustainable design (Suryawinata, 2021). Ahmed (2019) posits that VR technology effectively visualises sector planning, communication, and safety. Regarding physical construction, VR technology can effectively work on various safety methodologies and processes ((Zhang et al., 2022; Luo et al., 2023). VR impacts the construction industry as a technology with multiple uses, especially regarding cost savings, quality, safety, and the ability to virtually experience built infrastructure.

3.3 VR in Education

The built environment education (architectural design and construction) looks to implement more commercially available VR technologies into the curriculum as VR was previously perceived to be expensive, difficult to attain, and requiring specialized facilities and facilitators. In 2006, 'Virtualsite' (a virtual reality multi-media) created virtual construction site tours for students. This enhanced student experiences in teaching and learning as it could mimic sites through visualisation (Horne & Thompson, 2008). VR has been implemented in built environment education for around two decades. With VR being more accessible, students can create several simulations and make adjustments that may have been expensive or dangerous to replicate in the real world. Through these simulations, students can even make impulsive creative designs and get instant results on the feasibility of it. VR facilitators in built environment education find that students better understand when viewing multifaceted designs and structures spatially(Alizadehsalehi, Hadavi & Huang, 2019).

4 METHODOLOGY

For this study, a bibliometric analysis approach was utilised. This methodology has proved to be rigorous as a quantitative approach to analyse large data sets. It has proved helpful in various research domains to map a field's current state and observe nuances and development (Donthu et al., 2021). The authors use this methodology to explore the knowledge structure and visually map and analyse the field of "Virtual Reality" in the domain of "Built Environment Education" on the continent of "Africa". Data using the term "Virtual Reality" between 1994-2024 was exported using Scopus. Figure 1 represents the searching, screening, and inclusion procedure.

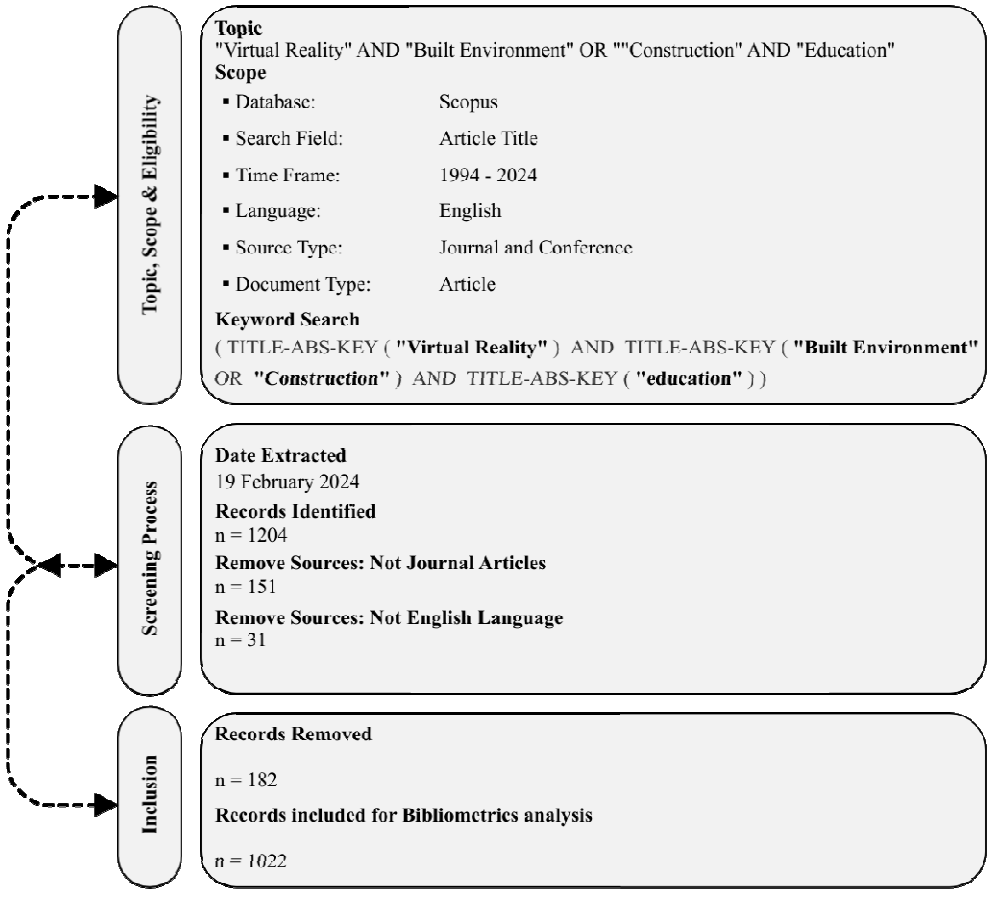

Figure 1: Methodological workflow of the Bibliometric analysis.

The main aim of this research is to investigate the research landscape of virtual reality in built environment education in Africa. Therefore, the study has been designed to unpack the knowledge structure of the field by using the following research questions:

- What is the conceptual knowledge structure of the field?
- What is the intellectual knowledge structure of the field?
- What is the social structure of the field?
- How does Africa fit into the body of knowledge?

Following the collection of data from the Scopus database, it was imported into Bibliometrix to conduct the analysis (Aria & Cuccurullo, 2017). Concluding the analysis, data was exported to VOS Viewer for graphical representation. Responding to the research questions, the authors mapped its knowledge structure. To achieve this, conceptual, intellectual, and social frameworks were used to explore the body of knowledge (Samiee & Chabowski, 2012). A keyword co-occurrence analysis was used to map the conceptual structure of the field, a document and author co-citation analysis was used to map the intellectual structure and a document co-authorship was used to map the social structure. Each technique discovered deep patterns, which are usually missed without this approach. The investigation methodology of these structures is detailed in the analysis section of this research. To conclude the research, the analysis of the knowledge structure revealed elements of how Africa, as a contributor of knowledge, fits into the network.

5 RESULTS, ANALYSIS AND DISCUSSION

5.1 Analysis of Annual Publications

It is critical to understand the publication trend over several years to determine the level of interest within that given domain. For this study, the researchers used bibliometric data over 30 years between 1994 and 2024. Referencing Figure 2, between the period 1994 to 2016, the publication rate in this field was relatively slow. Although the trend is upward, during this period, the general norm was a peak followed by a trough. A significant increase in publications from 21 documents in 2016 to 47 papers in 2017, representing 4,60% of the cumulative total of publications in this area of research over the 30 years. This upward spike in research is due to the launch of consumer-orientated VR systems by companies such as Oculus, HTC, and Valve (Sherman & Craig, 2018). VR products' commercial availability meant that they were readily available in the market and could be used by anyone. The trajectory forward shows a significant increase in publications between 2020 and 2021, almost doubling publication documents. Considering the COVID-19 pandemic in this temporal scope, evidence suggests that researchers were looking at remote teaching, especially in fields requiring immersion. In 2023, the research interest in this field tapered off. This could be for many reasons, including the end of pandemic measures or no significant technological development to report. Overall, the publication trend indicates substantial growth in this area of research.

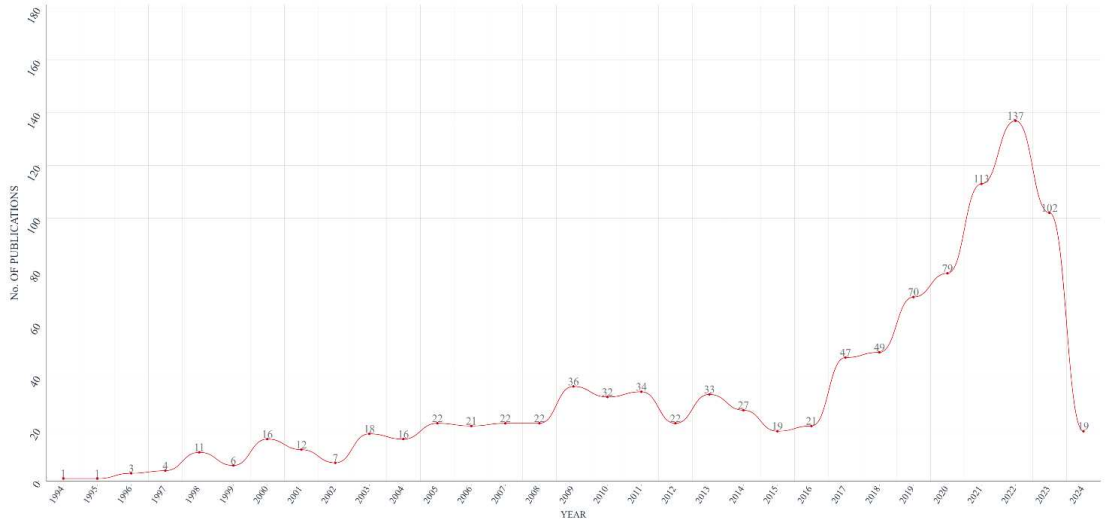

Figure 2: Graph depicting the publication trend of the topic area between 1994 and 2024.

5.2 Intellectual Knowledge Structure of the Field

In this research segment, the authors use science mapping to represent the intellectual structure of the field. In direct response to the first three research questions and the development of the overall research aim. The conceptual, intellectual, and social structures will be analysed to conduct this procedure. The global body of knowledge must be represented before distilling down to the specific focus of this research. Therefore, the intellectual knowledge structure is created and represented as a base of analysis.

5.2.1 Conceptual Structure

The second set of data analysed for this study consisted of a keyword co-occurrence network analysis. Drawing from the upward trend in research publications from the first data set, it is critical to analyse which research areas are in high demand within the keyword variables, answering the first research question. During the sorting of data, 6,281 keywords were exported from the Scopus database, and a minimum of 5 co-occurrences, of which 399 words met the threshold. This created 8 clusters and a total of 12670 links with a link strength of 31512.

The top 10 preferred keywords from the data are listed in Table 2. Compared to the total publications exported, an undeniable link between Virtual Reality and E-learning, Engineering Education and Students is present. This data reveals a strong focus on using Electronic Learning Technologies such as VR in education, especially engineering education. To further investigate the pertinent topics in this field, a network map was created in VOS Viewer with a temporal overlay (2014-2024) to understand the research trend. The research areas that move between orange and red are new or emerging research areas. Although Engineering Education features highly in several publications, the research interest in this field has slightly tapered away. E-learning remains high on the agenda with strong links to curricula, virtual reality technology, learning systems, students, and education computing. This relationship shows that E-learning is closely related to those fields, and the relationship between these keywords is evidence of educational disciplinary collaboration. Emerging research in this area comes from themes such as Metaverse, Virtual Simulations, 3D Modelling, Simulation Platforms, and E-learning. Representation of these areas appears smaller, represented as darker orange and red. However, this is evidence of a research gap.

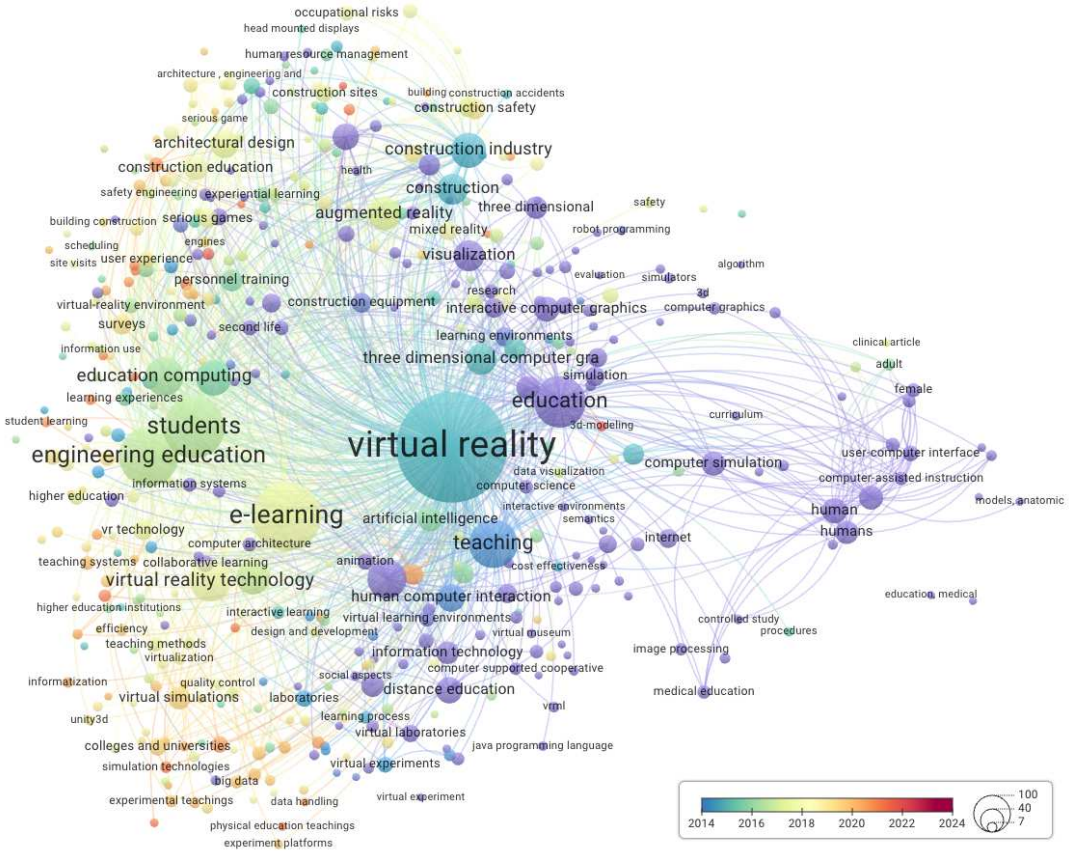

Figure 3: Visualised network map of research themes, overlay between 2014 and 2024 (10-year period) to understand the trajectory of research themes.

Author Keywords	Occurrences	Percentage (%)	Link Strength
Virtual reality	803	14,50%	5922
E-Learning	326	5,89%	2765
Engineering Education	265	4,79%	2317
Students	260	4,69%	2353
Education	190	3,43%	1560
Teaching	163	2,94%	1578
Virtual Reality Technology	118	2,13%	961
Education Computing	109	1,97%	1062
Computer Aided Instruction	96	1,73%	869
Construction Industry	87	1,57%	881

Table 1: The top 10 Keywords in the research network.

5.2.2 Intellectual Structure

In data set three, the focus is moved to the intellectual structure of the field. Therefore, a co-citation analysis utilised document and author coupling to determine the intellectual knowledge structure. Co-citation analysis, developed by Henry G. Small, advocates that a citation symbolises an idea or concept (Small, 1978). Co-citation analysis is a powerful method where citing authors is central to the metric. A set of two identical articles is termed co-cited when it appears in the reference list of a new article; the frequency at which this occurs over some time results in a count of co-citation occurrence. Small (1973) interprets the idea of larger co-citation count as a measure of similarity or co-occurrence of ideas. Furthermore, he advocates that co-citation is a powerful measure because, over time, new documents or authors with new ideas become central to the focus and are co-cited; thus, it is possible to track knowledge development (Small, 1973).

Document Co-citation Analysis.

To determine the formation of the body of knowledge, the authors opted for a document co-citation analysis to reveal the underlying concepts and theories used to create this niche topic. The ten largest nodes are used to determine the centrality of knowledge and network formation. Each node represents a highly cited document, the size of the document is the normalised citation count, the thickness of the link line represents the frequency of co-citation, and the proximity of the two nodes represents the thematic relationship. The addition of a temporal scope helps in understanding the development of the field over time.

As the pedagogical foundation for this research, Node 6 and Node 2 are essential in the network and represent the underlying theories and concepts of experiential learning and situated learning. Kolb (1984) articulates that through life experience, great learning occurs due to direct sense experience and in-context action. Lave & Wenger (199:14) compound that learning is inextricably linked to actional contexts and not self-contained structures, which they term legitimate peripheral participation. The two authors clearly state that learning in a realistic environment allows students to gain experience without total responsibility. It is clear why these authors are critical in forming this knowledge area; the theories are central to learning and act as a support structure for using Virtual Reality technology in a learning environment. Furthermore, VR technology can allow students to be immersed in a real-world environment while participating in skill development without risk and responsibility.

Building upon the ideas of Node 2 and 6, Node 10 unpacks the idea of presence. Steuer (1995) reveals that virtual reality in various bodies of knowledge is defined by the idea of technology but devoid of the human experience. He argues that virtual reality is a communication medium through which a human can experience presence in a mediated environment and uses this telepresence(Steuer, 1995). The author's ideas give rise to the need to create an environment that allows the human being to be aware of the virtual environment by stimulating the senses to create a lifelike experience. Node 4 builds upon the experience of the environment and unpacks the ideas of immersive environments. A study by Paes, Arantes & Irizarry (2017) reveals that immersion in a virtual-environment results in a better spatial understanding. Therefore, virtual reality technology must always be able to interact with the senses and immerse the user to take full advantage of the experience. Node 5 introduces the concept of simulation within the VR environment.

Node 9 is a pivotal piece of literature in the context of Virtual Reality in the Built Environment. Considering the temporal location of the book, the author introduces the use of VR in the planning, design, and construction process (Whyte, 2003). Therefore, the literature is seminal in introducing the built environment fields to VR technology. (Zyda et al., 2005) advocate for the need to introduce gamification to Virtual Reality simulations so users can interact well with it linked to an outcome.

Node 8 is a critical juncture in the field of education. Although this paper is not the first to introduce the VR concept to education, the document reviews findings from several other papers over ten years (1999-2009). Therefore, it is likely that several authors in the field use this document as a source to study the state of the art. Node 3 moves the discussion into the construction profession to build on the findings in an educational context. (Wang et al., 2018)e the most studied areas in VR-integrated construction education.

At the centre of the network, Node 1 acts as the main bridge in knowledge flow in the fields. This indicates that the paper by Sacks, Perlman & Barak (2013) integrates a large body of knowledge in various areas. On closer inspection, the study integrates the various knowledge areas to conduct an empirical study with rich results. One is creating a virtual construction site where safety training can occur. Although the paper's title is focused on construction safety, the content is central to the greater knowledge body, integrating several concepts. Node 7 moves the discussion to the practical implications of the technology and the need to improve or enhance the current methodologies and, therefore, enhance their position in the knowledge body(Eiris, Gheisari & Esmaeili, 2020).

Year	Article	Node	Key Themes	Betweenness Centrality
1984	Kolb, D.A., 1984. Experiential learning. Experience as the Source of Learning and Development, 41.	6 Pink	Experiential Learning	236.06
1991	Lave, J. and Wenger, E., 1991. . Cambridge University Press.	2 Grey Blue	Situated Learning	595.52
1995	Steuer, J., Biocca, F. and Levy, M.R., 1995. Defining virtual reality: Dimensions determining telepresence. *Communication in the age of virtual reality*, *33*, pp.37-39.	10 Light Orange	Virtual Reality	144.24
2003	Whyte, J., 2003. Virtual reality and the built environment. *Presence*, *12*(5), pp.550-552.	9 Dark Blue	Virtual Reality in the Built Environment	156.97
2005	Zyda, M., Mayberry, A., McCree, J. and Davis, M., 2005. How We Built a Hit Game-based Simulation.	5 Light Pink	Game Based Simulation	339.09
2011	Mikropoulos, T.A. and Natsis, A., 2011. Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education*, *56*(3), pp.769-780.	8 Grey	Virtual Reality in Education	163.33
2013	Sacks, R., Perlman, A. and Barak, R., 2013. Construction safety training using immersive virtual reality. *Construction Management and Economics*, *31*(9), pp.1005-1017.	1 Orange	Virtual Reality in Construction safety training	978.94
2017	Paes, D., Arantes, E. and Irizarry, J., 2017. Immersive environment for improving the understanding of architectural 3D models: Comparing user spatial perception between immersive and traditional virtual reality systems. *automation in Construction*, *84*, pp.292-303.	4 Yellow	Immersive Environments	381.16
2018	Wang, P., Wu, P., Wang, J., Chi, H.L. and Wang, X., 2018. A critical review of the use of virtual reality in construction engineering education and training. *International journal of environmental research and public health*, *15*(6), p.1204.	3 Cyan	Virtual Reality in Construction Education	390.14
2020	Eiris, R., Gheisari, M. and Esmaeili, B., 2020. Desktop-based safety training using 360-degree panorama and static virtual reality techniques: A comparative experimental study. *Automation in construction*, *109*, p.102969.	7 Light Brown	Virtual reality and Safety training	182.57

Table 2: Top Ten documents creating the knowledge flow in the document co-citation network.

Author Co-citation Analysis

To further map the research field, the authors opted to conduct an author co-citation analysis to identify the main authors in the field and their research directions. This is critical in understanding the intellectual knowledge structure and which authors influence and create connections within the field (Song, Wu & Ma, 2021). To conduct the analysis, the authors used the entire cohort of authors and then applied a minimum of 30 citations as a cut-off, of which 68 authors met the threshold. Results revealed that author Wang X is a central part of the network; the high number of citations evidence this. The work of Wang X is central to robotics in the construction industry, therefore placing them at the centre of this research network. Gheisari M appears to be the second most cited researcher in the network; their work in construction education using VR technologies places them as a large node in the network, evidenced by 148 citations. Li H comes in third with 113 citations; their work is concentrated within digital technologies in construction, making them a vital node connecting academia and industry. Sampaio AZ's work focuses on pedagogical approaches to VR, especially in civil engineering education. Therefore, their work forms an integral node, moving knowledge and acting as a bridge to focused areas of construction education. Jalal A sits on the periphery of the network. Studying the works of Jalal A, the author's works are in computer science; however, the technology discussed within the author's oeuvre supports new developments and integration within this network.

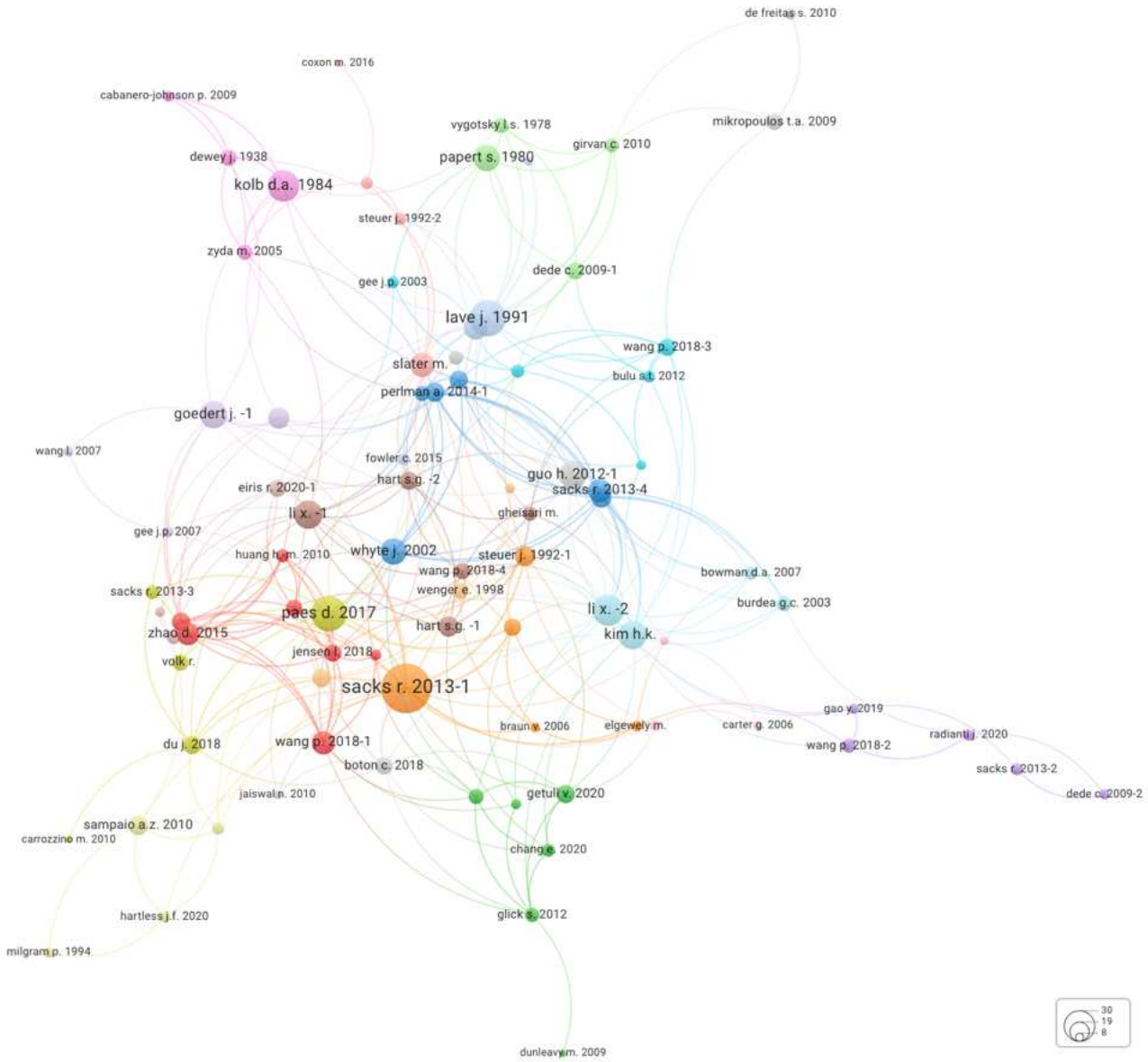

Figure 4: Visualised document co-citation network map of Virtual Reality in Built Environment Education.

No.	Author	Speciality	Citations	No. of Publications
#1	Wang X.	Construction Science	174	6
#2	Gheisari M.	Construction Management	148	12
#3	Li H.	Construction Informatics	113	5
#4	Sampaio AZ.	Civil Engineering	99	21
#5	Jalal A.	Computer Science	82	1

Table 3: Author co-citation analysis indicating the main authors within the network.

5.2.3 Social Structure

In the final data set, the authors mapped the social structure of the field. This approach explored how authors within the network and countries collaborate towards the knowledge body. Two methods represent the social structure of the network to understand the collaboration patterns. First, Co-author links are mapped to understand the collaboration groups and their links to the network. The respective countries are mapped to understand collaborations in the research network.

Co-authorship Analysis.

Scientific collaboration is a critical part of the nature and development of knowledge for the greater good. The need for collaboration occurs when opportunities such as new knowledge, specialisation, equipment, and skill sets exist. However, other reasons may create the need for collaboration, such as institutional or country goals. The authors used a co-authorship analysis to explore the social construct of the intellectuals that form the research network. This study discusses the largest collaborator in the five largest nodes. Gheisari M has

the largest number of collaborations in their node, with a link strength of 22. Gheisari's network's top five interests are virtual reality, construction education, 360-degree panoramas, and drones. Teizer J holds the second-largest network, and its interests revolve around training, virtual reality, education, construction safety, and health. In the third largest network, central around Lin Y, topics including virtual reality, intelligent manufacturing, campus navigation, Chinese culture, and developed flow are commonplace. The fourth largest network is represented by Chen Y, and focus areas are central to adaptive education systems, digital intelligence technology, film art creation, virtual reality, and AR technology. Nikolic D, the central node of the fifth group, focuses on construction education, construction management, 4D simulation and development frameworks.

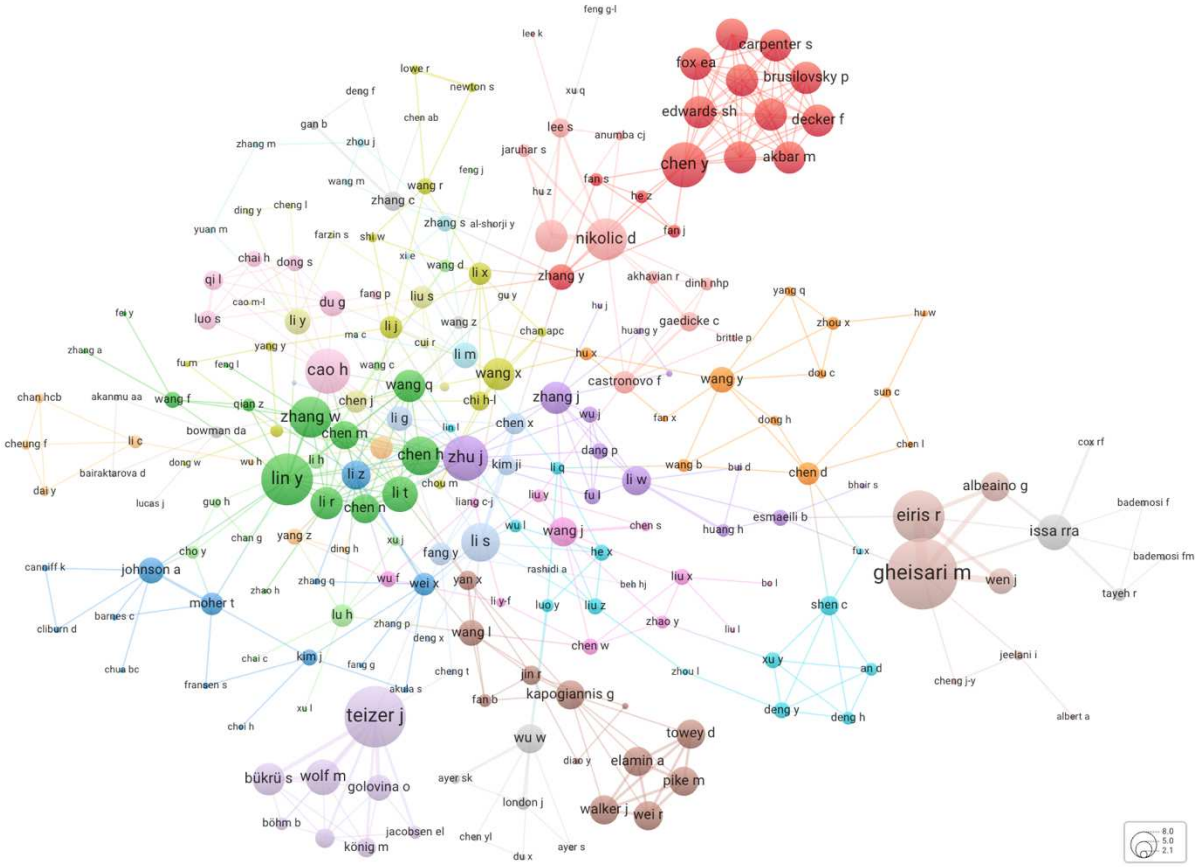

Figure 5: Visualisation of co-author network.

Country Collaboration Analysis.

Within the global knowledge society, it is critical to understand the collaboration of countries to unpack where the influential authors emanate from as well as their global ties. By conducting this analysis, patterns of collaboration reveal themselves. In this segment of the research, the top five collaborators are discussed. The biggest collaboration in the research network is between China and the USA, with 11 joint publications. In the second place, collaborations between China and Hong Kong sum up to 10. In third place, five publications exist between the USA and the United Kingdom. The USA and Egypt have four joint publications in fourth place. In fifth place are China and Japan, where there are three publications. The USA dominates collaborations with 22 connections to other countries, followed by China with 16 and the United Kingdom with 15.

5.2.4 Africa in the Knowledge Network

The data analysis throughout this study is a fair indicator of the amount of research carried out globally; consequently, it reveals a paucity of research within the African context. Throughout the study, none of the authors or publications linked to Africa show up within the top ten metrics. This result is an indication of various structural challenges. Only 18 articles have emanated from the entire African continent, with 62 citations. Contribution from the continent is low, with 18 papers, but some impactful articles have been

produced. Nine papers are journal articles, of which six were published in journals with an impact factor greater than 3,5. Considering that the 14 publications were from the past five years, the citation count is reasonable for the time.

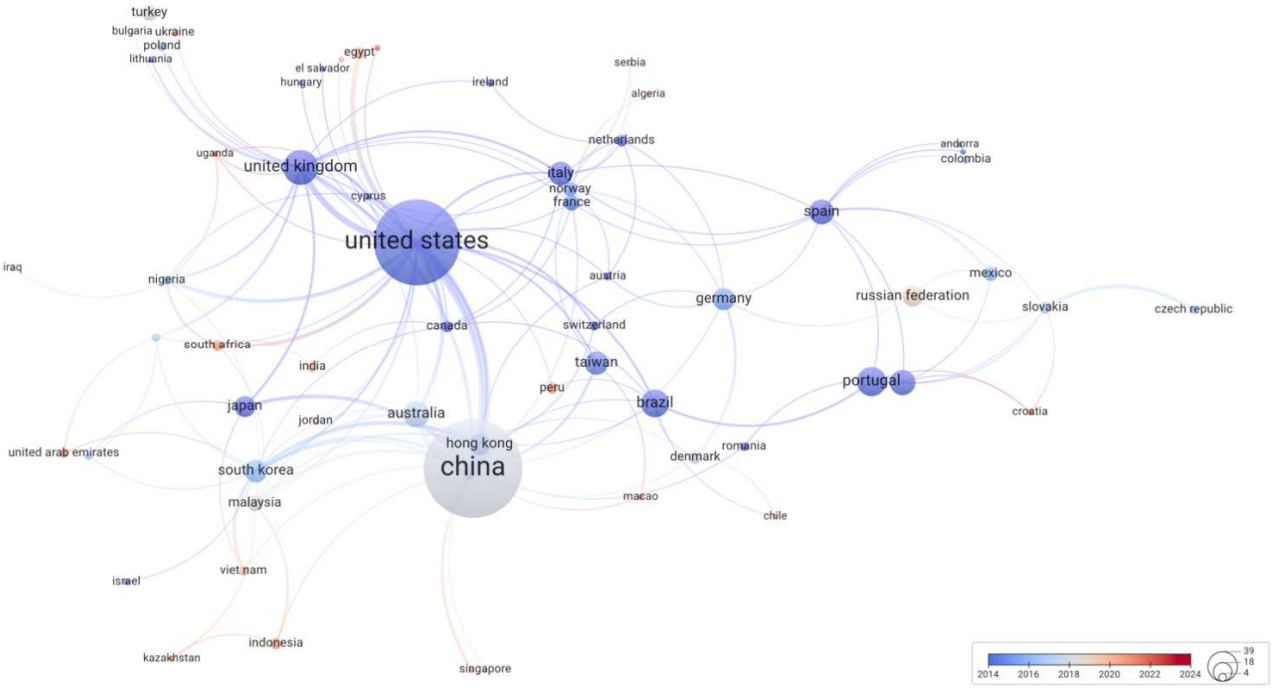

Figure 6: Visualisation of country collaboration network.

Regarding contribution to a similar set of keywords, the papers follow the same trend as their international counterparts. Some additional keyword co-occurrences, such as construction education, construction sites, building information modelling, construction, and performance, enter the debate. These words also appeared within the global keyword occurrence. However, some nuanced research areas seem more prevalent in Africa.

Running a co-citation analysis on the data set at present will result in skewed results. Due consideration is taken for the age and number of publications. Although, at present, the research emanating from Africa is low, a great need to investigate certain niche areas can be severely beneficial. For example, VR is a low-cost means to visit international construction works virtually for students and professionals alike. In terms of co-authorship, none of the authors within this study has formed strong co-authorship networks, locally or within the global body. Only eight links have been created on the continent, two of which are between African countries.

6 CONCLUSION

The study set out to investigate the research landscape of Virtual Reality in Built Environment Education through a Bibliometric methodology. Data exported from Scopus was analysed using Bibliometrix and visualised using VOS Viewer. The analysis revealed that the fourth industrial revolution increasingly significantly influenced publications in the network. The keyword co-occurrence revealed that Virtual Reality technology has significant ties to education and the built environment and is becoming a popular medium of representation, training and education. Future directions include Metaverse, Virtual Simulations, 3D Modelling, Simulation Platforms, and E-learning. These topics are new, and a paucity of research exists within this network. New empirical studies can bridge several gaps within the network.

The document co-citation analysis revealed the intellectual structure of the network. Education and psychology theories and concepts assist in creating a strong foundation for the use of VR in the setting of construction education. Equally, the seminal papers advocate for the environment to be central to the learning experience. VR technology bears this weight, especially if the intention is to immerse the user. The idea of VR technology being a rewarding experience is also important; some gamification frameworks are critical in the entire network development. Although several papers exist in the body of knowledge, few have

recorded how students of construction. use and experience the technology. There is a gap in exploring this idea through a longitudinal study.

Analysing the authors' profile, a large amount of research is carried out by professionals from the construction management discipline, followed by civil engineering. There is some evidence of research in architectural education; however, more effort is required to streamline the technology and pedagogical approach. Professions such as Urban planning and design, quantity surveying, and landscape architecture are almost non-evident, leaving a gap in the overall network.

The collaboration patterns show that some internal country clusters have developed, and knowledge is generated within the group. International connections exist; however, these ties are weak between authors. More effort on international joint efforts is required to move this area of research forward. African researchers must create international connections, especially with the USA, China, and the UK. The current construction processes within Africa can be impacted severely by collaborating with international partners. However, other countries may benefit more from lessons from Africa.

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ISEK⁴ – A Regional Approach to Inner City Development

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1 ABSTRACT

Integrated planning approaches provide the toolkit for delivering holistic and interdisciplinary solutions to meet the complex challenges of the 21st century. However, established instruments such as the integrated urban development concept (ISEK, common in Germany) lack the multilevel spatial integration required to tackle these issues effectively. Designed as a pilot project for the development of a new planning instrument, ISEK⁴ addressed two spatial spheres that – despite obvious necessity – are rarely considered together in the existing planning toolkit: the inner city and the functional region. Within eight months, integrated urban development concepts for the inner cities of Bruneck (South Tyrol), Hermagor-Pressegger See (Upper Carinthia), Lienz (East Tyrol), and Spittal an der Drau (Upper Carinthia) were developed along with a regional symbiosis of the SOUTH ALPINE SPACE, demonstrating and using synergies between the inner cities as anchor points of public life in the region. The ISEK⁴ project was based on a transdisciplinary planning approach and developed together with local steering groups from the cities. During the project, knowledge and needs were collected, recorded, and spatially contextualized in different workshop settings. In the work process, a mixed methods approach comprised of qualitative (GIS accessibility analyses, heat mapping) and qualitative (visioneering, storytelling, document analysis, design thinking lab, etc.) planning and research methods was employed. The central outcome of the ISEK⁴ project was a joint regional vision of the future, in both which local potentials and characteristics as well as regional strategies for action are represented. Alongside a geographically warped future image of the region, a vision story was used to outline the key areas of joint action. The ISEK⁴ concept also contains four city-specific sections (local ISEKs) drawing upon the so-called regional guiding principles, which are combined in one joint document. The key innovation of the project was the simultaneous consideration of four municipal city centres within a regional framework. It was shown that through the symbiosis of multiple concepts, activities in the field of inner-city development can be bundeled strategically and, in many cases, also implemented together. This paper focuses on the work process, the lessons learned and the transferability of the project approach, as well as selected results. A special focus will be on the methodological aspects of the storytelling method that was employed in the design of the regional and local future visions for ISEK⁴.

Keywords: Regional Symbiosis, Inner Cities, Urban Development, Alpine Space, Integrated Planning

2 INTRODUCTION

Integrated (inner) city development concepts (ISEKs[1]) are a modern approach to sectorally and spatially integrated planning in cities. They are aimed at managing strategic investments with the intention of

[1] An ISEK outlines the scope of action as well as objectives, intervention fields and measures for a period of several years (cf. Heinig, 2022). The informal nature of the planning tool allows spatial and thematic priorities to be defined for specific locations. An ISEK identifies actions that can be implemented in the short term and at the same time provides a

strengthening urban districts (usually central areas). So far, ISEKs have primarily been established in Germany, where they form a precondition for financial support from the federal government within the framework of urban development funding ("Städtebauförderung"). While the instrument is generally well suited to unlocking local or municipal development potentials, it rarely provides incentives for thinking and plnanning beyond the (geographical, and also thematic) horizon of the specific city. The experimental research project ISEK⁴, conducted by TU Wien in 2022, provides a possible approach for the evolution of the planning tool. ISEK⁴ – the second integrated inner city development concept to ever be developed in Austria following the ISEK Wolfsberg in 2021 – addresses the local needs for action in four different cities simultaneously and integrates them under a shared strategic umbrella.

3 STUDY AREA – THE SOUTH ALPINE SPACE

The ISEK⁴ project was realized within the spatial context of the SOUTH ALPINE SPACE, a highly dynamic cross-border region that spans two states – including one Italian and two Austrian provinces. Stretching from north-eastern part of South Tyrol (IT) via East Tyrol (AT) all the way to Upper Carinthia (AT), the region displays Alpine and Mediterranean influences at the same time. The four cities of Bruneck (IT), Lienz, Spittal an der Drau and Hermagor-Pressegger See (AT) have been connected through an informal cities network since late 2019, when a charter outlining the principles and objectives of the regional cooperation activities was passed. The region has since continued to strenghten its cooperation efforts by issuing the Strategic Framework for the Development of the SOUTH ALPINE SPACE in which a mission statement was formulated and the systemic approach to the future collaboration was laid out (cf. Regionsmanagement Osttirol, 2021).

The SOUTH ALPINE SPACE region is spatially characterized by the interplay of the valleys and mountain ranges that surround the cities and smaller municipalities. Besides serving as import infrastructural corridors, the valleys also shape the cultural and natural landscape of the region. At the same time, the mountains form incisive spatial barriers between the settlement areas. The four cities involved in the ISEK⁴ project share the advantages of being situated along alpine rivers (Rienz, Isel, Drau, Gail) and having direct access to the railway network. These similar spatial circumstances create ideal conditions for mutual learning processes, as well as a common vision of inner city development.

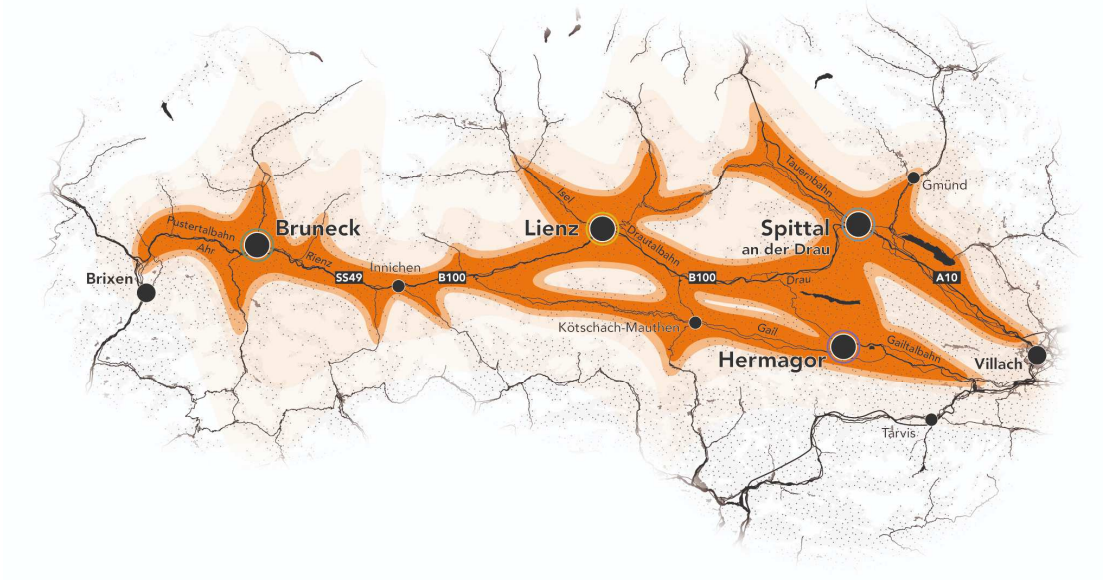

Fig. 1: Scheme of the region

Through regional railways, the SOUTH ALPINE SPACE is well-connected to the long-distance railway network. This includes major national and international connections, for instance from Lienz and Spittal an der Drau towards Vienna, Zürich or Zagreb. Through large infrastructual projects aimed at the expansion of

long-term view of the future. It takes into account the interactions of holistic and integrated development as well as the regional and city-wide spatial framework.

Trans-European Networks (TEN-T, e.g. Brenner and Semmering base tunnels, Koralm Railway), the accessiblity of the region will be further improved in the coming years (cf. Kunzmann, 2015). Well developed cycle routes along the region's rivers, sections of which are part of the EuroVelo network, also form an essential part of the mobility infrastructure. At present, these routes are already of great importance for summer tourism. The establishment of new international connections (e.g. the Munich-Venice long-distance cycle route) is expected to lead to further growth in cycle tourism in the region (cf. Tscherne, n.d.).

Even though the region was originally defined along district and regional boundaries, the SOUTH ALPINE SPACE does not consider itself a mere aggregation of administratively isolated container spaces, but rather a functional space that is aware of its long-standing relationships with the surrounding regions out (cf. Regionsmanagement Osttirol, 2021, pp. 9-15). For instance, there are strong links with the neighboring Italian provinces of Belluno and Friuli as well as with the urban region of Bolzano and the central Carinthian metropolitan area (Klagenfurt, Villach). The interaction manifests itself, among other things, in the sharing of infrastructure, commuter relations and collaboration in the management of (alpine) natural hazards.

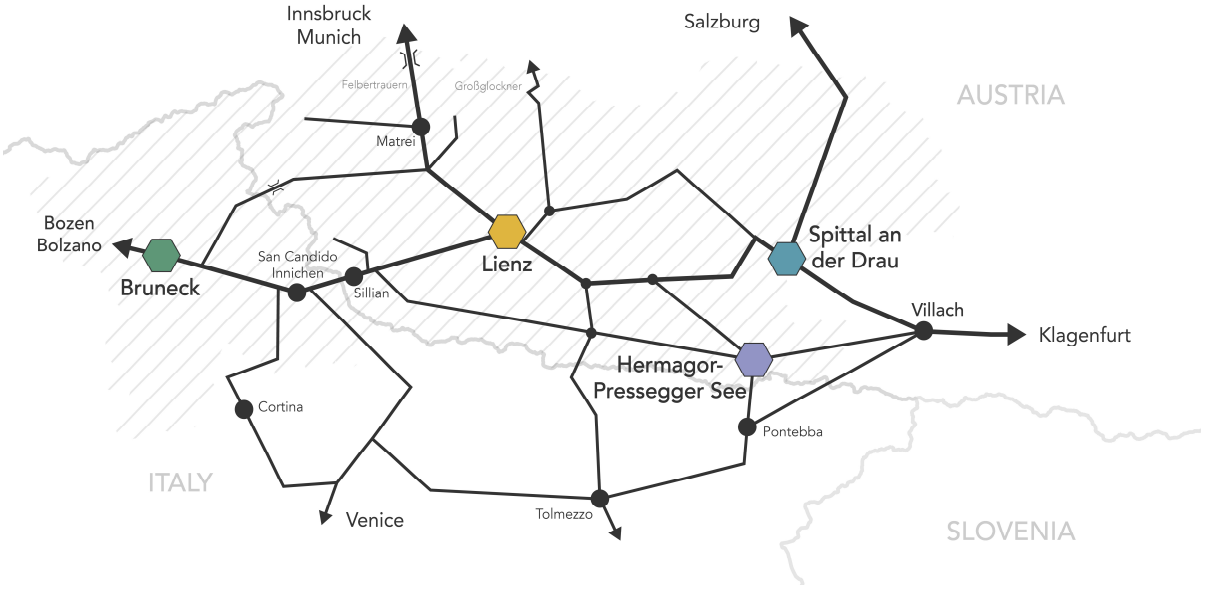

Fig. 2: The SOUTH ALPINE SPACE – connections and supra-regional links

4 THE ISEK⁴ PROJECT

The idea for ISEK⁴ came about at a time of intensive debates regarding the possible introduction of an urban development funding programme in Austria. The existence of an ISEK was discussed to be a precondition for funding eligibility. At this stage, the Austrian Conference on Spatial Planning (ÖROK) published ten expert recommendations dealing with the legal, administrative and instrumental framework conditions for strengthening city and town centers. Among other things, it proposed the elaboration of integrated urban development concepts (ISEKs). The document also contains very specific recommendations for the technical work involved in developing such concepts (cf. ÖROK, 2019). The SOUTH ALPINE SPACE cities network decided to tackle the task of inner city development together and to include the regional level.

The ISEK⁴ project was funded from several sources. In addition to an INTERREG funding for cross-border cooperation between Bruneck (South Tyrol) and Lienz (East Tyrol), the Austrian Federal Ministries for Climate Protection (BMK) and Agriculture (BML) as well as the province of Carinthia also supported the project. The work process was completed within ten months and covered a period from May 2022 to February 2023 (cf. Hirschler et al. 2022).

The ISEK⁴ concept was developed in a collaborative planning process involving local steering groups from the four cities, each composed in a gender balanced way. The formation and size of these groups varied from city to city (between four and twelve people). The steering groups acted both as local development partners and as valuable information sources for the project team. There was a regular exchange between the steering groups and the TU Wien team throughout the project.

Fact Box: ISEK⁴

Project Contractors

City of Bruneck, City of Hermagor-Pressegger See, City of Lienz, City of Spittal an der Drau

Project Period

May 2022 – February 2023

Funding

INTERREG (cross-border cooperation between Lienz and Bruneck)
Austrian Federal Ministry of Climate Action (BMK)
Austrian Federal Ministry of Agriculture (BML)
Province of Carinthia (Land Kärnten)

Fig. 3: Project Fact Box

The first stage comprised a space- and actor-specific analysis, in which existing local concepts, plans, strategies and projects (ongoing or recently completed) from the four cities were screened in a secondary analysis. Possible development scenarios were discussed on the basis of a so-called opportunity-deficiency plan during participatory design workshops. The integrated assessment of the key issues from the analyses helped in defining objectives and developing local and regional future visions. These basic visions were refined in local strategy workshops and supplemented with specific strategies for action. At the subsequent project marketplace, workshop participants had the opportunity to present ideas for possible measures at a local or regional level within an open setting. Concurrently, the ideas and suggestions of the young local community were also collected at the young experts workshops.

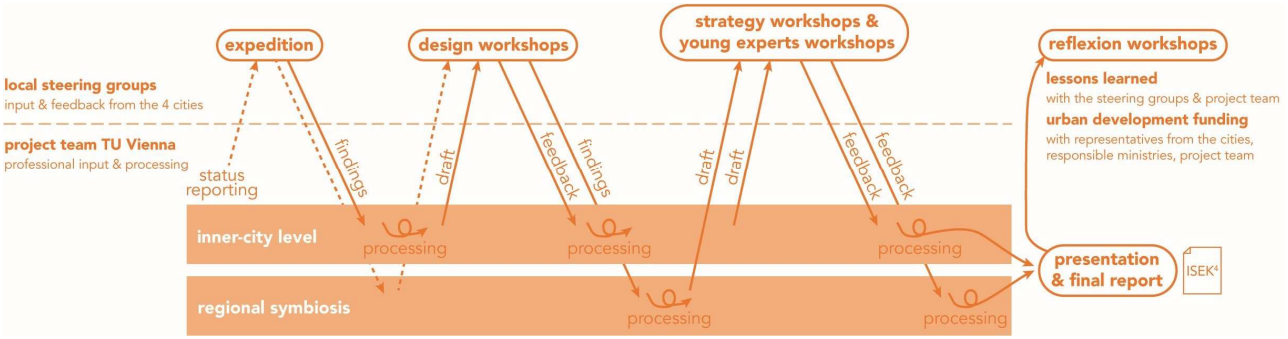

Fig. 4: Development process of the ISEK⁴

5 METHODS AND APPROACHES

At the outset of the project, the focus was initially placed on identifying the key factors for the city center development. Building on the screening of existing concepts, plans, strategies and projects described above, specific thematic primary analyses were added. For instance, GIS-supported network analyses provided insights on the accessibility of city centers by foot or bike. Using the storytelling method (cf. Sandercock 2003, Throgmorton 1992), the situation assessment was condensed into an experience report from the perspective of a person strolling through the city. Based on the initial analytical findings, so-called focus areas were outlined for which the need for short to medium-term action could be identified. Several excursions to the focal areas supported the spatial delimitation and provided the project team with new perspectives on the existing urban fabric. On the regional level, a multi-layer structural analysis was carried out to identify topographical, functional and infrastructural similarities between the cities. In conjunction with the findings from the local analyses, key regional themes ("regional guiding principles") emerged that were accessed in all stages of the subsequent ISEK⁴ process.

During the participatory design workshops, the visioneering method (cf. Salzmann 2013) was used in the development of future visions for the four inner cities and the SÜD ALPEN RAUM. The method makes use of various (audio-)visual techniques (e.g. photo collages, storytelling or mental maps) that make spatial development ideas more tangible for the people involved. With the aim of incorporating the regional level of action into the process, the workshop participants were also asked to reflect on the positioning of their city

within the SOUTH ALPINE SPACE. Furthermore, (everyday) action areas in the region were located on a map (housing, work, education, shopping and leisure).

In the strategy workshops, which were held in all four cities in late September 2022, the graphical visions for the future of the inner cities and the region that had been prepared by the ISEK⁴ project team were enhanced together with the workshop participants. The Design Thinking Lab method (cf. Lewrick, Link and Leifer 2020, pp. 17-27) was used to identify open questions and develop concrete strategies for action. In the subsequent project marketplace, the project canvas method was used (cf. ibid., 309 f.) to create basic outlines for the implementation ideas (objectives, timeframe, funding, impact, stakeholders, users, etc.). The resulting project drafts were later condensed by the project team and structured according to their relation to the regional guiding principles. Finally, the project proposals were assigned to two categories - either local or regional.

Digital, hand-drawn visualizations have been used as a characteristic design form and permeate the entire ISEK⁴ concept. They spatially visualize abstract objectives and strategies using specific situations, symbolic representations and (in some cases) graphic exaggerations.

5.1 Application of the Storytelling Method

A key to the success of good spatial planning is being able to convey complex matters in an understandable and relatable way. Therefore, in a project like the ISEK⁴, which not only considers a variety of topics in an integrated manner, but also combines two different spatial levels, the use of the storytelling method is particularly suitable. The approach helps in forming the course of spatial changes based on existing situations and in preparing development paths in an understandable way for those affected by planning (cf. Schoberleitner, 2021).

The method was employed in various stages of the ISEK⁴ development process. Initially, experience-based stories written from the perspective of a pedestrian were used to convey the current status of the inner cities. These “situation assessments” not only point towards ongoing projects that were identified in the secondary document screening (e.g. the NOI Tech Park under construction in Bruneck) but also refer to findings from primary analyses (e.g. to the walking times extracted from GIS network calculations). Finally, they also include subjective impressions and experiences gained during the focus area visits, as well as aspects mentioned by on-site experts in the local workshops. The storytelling approach was also used in the presentation of the initial draft for the graphical future vision of the SOUTH ALPINE SPACE during the strategy workshops. At the start of the workshops, a short text was read out, picking up the contents of the regional vision image and translating them into specific everyday situations experienced by the region's inhabitants of the future. Despite initial slight confusion, the workshop participants quickly picked up on specific aspects of the future story to communicate their suggestions for the graphical future visions. This way, storytelling helped to initiate a lively (yet constructive) discussion between the local experts and the project team.

Lastly, storytelling passages became vital building blocks of the final ISEK⁴ concept report. In conjunction with drawn digital images, stories were used to convey the local and regional future visions from the perspective of an architect named Anna. Through real-live situations, objectives and recommendations of the ISEK⁴ concept are presented in a tangible way.

6 RESULTS

The need for intensified regional cooperation is reflected in the concept and structure of the ISEK⁴ final report (Fig. 5). The underlying aim is to consider regional framework conditions, potentials and objectives in combination with local activities (cf. Hirschler et al. 2023, 23 f.). The decision to combine all four local ISEKs as well as the regional symbiosis into one overall document is intended to accommodate the spatial integration of the concept.

6.1 General Planning Framework

In order to facilitate a holistic approach to the future development of the four inner cities and the SOUTH ALPINE SPACE region, a general planning framework was developed first – a set of criteria that is supposed to form the basis for all activities, regardless of the spatial situation (city center, overall city or

functional region). These fundamental planning values were developed in a co-productive approach to ensure an inclusive, resilient and adaptable development. The framework comprises the following six aspects:

- Strengthening of cities and regions of short distances
- Land conservation and reuse of existing facilities
- Making and keeping cities resilient to climate change
- Ensuring equal opportunities for everyone
- Learning from each other and growing together
- Establishing a resilient SOUTH ALPINE SPACE

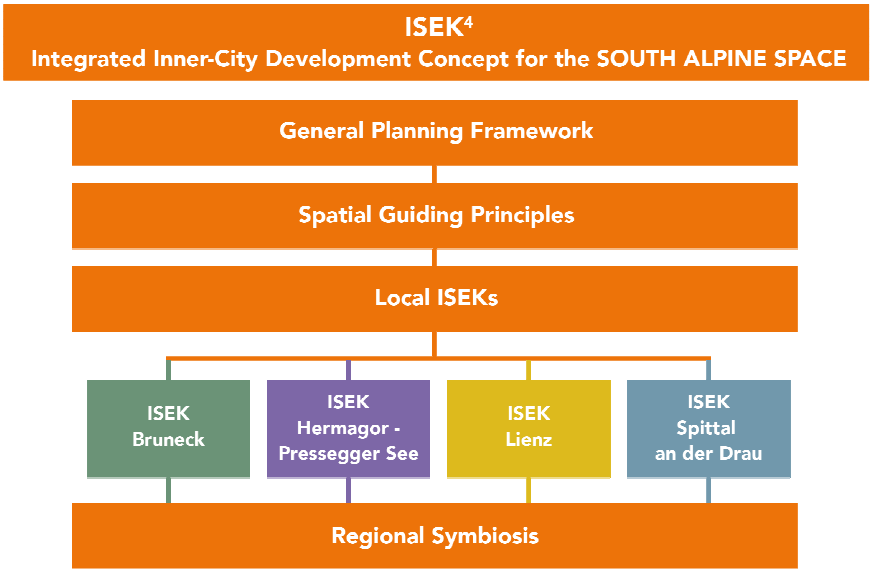

Fig. 5: Structure of the ISEK⁴

6.2 Spatial Guiding Principles

Based on this general planning framework, seven regionally specific spatial guiding principles were identified. They reflect common issues, challanges and opportunities identified in all four cities during the analysis stage. The spatial guiding principles link the general planning framework to the spatial development goals at the inner-city as well as the regional level. The spatial guiding principles link the general planning framework to the spatial development goals at the inner-city as well as the regional level. They can be found throughout the ISEK⁴, from the local visions of the future, the concepts and development ideas all the way to the regional symbiosis.

6.2.1 Riverbanks and Free Spaces – Perceptible and Nature-Oriented

A common characteristic of the four cities in the SÜDALPENRAUM is their location along one or multiple rivers, allowing for the achievement of high urban development qualities in the city centers. In times of advancing climate crisis, watercourses take over important cooling functions in the urban fabric and act as a natural air conditioning system. If riverbanks are designed in a nature-oriented way, rivers can also function as important biodiversity corridors within Alpine areas. ISEK⁴ therefore sets out the goal of removing visual barriers and improving the accessibility of inner-city watercourses (taking into account natural hazard protection). By creating connections to the pedestrian and cycle path network, the riverbanks will become anchor points within a dense network of green and open spaces in the inner cities.

6.2.2 Mobility Transition – Lived and Liveable

In terms of mobility, the focus needs to be significantly shifted towards walking and cycling in the foreseeable future. Given their size, the cities of the SOUTH ALPINE SPACE lend themselves ideally as cities of short distances. Virtually all important facilities and amenities can be reached within 15 minutes by foot, by bike or via supplementary mobility services (city buses, shuttles, sharing services, etc.). The reduction of transport-related CO_2 emissions can only be achieved through a densification of public transport

services, attractive supra-regional cycle paths between the centres and the promotion of active mobility in the cities.

6.2.3 Railway Station Districts – Integrated and Activating

In this context, railway stations and their integration into the urban fabric are also becoming increasingly important. Acting as mobility hubs, they connect (supra-)regional to local transport networks. At the same time, a broad spectrum of uses is clustered at railway stations: Local amenities, gastronomy, meeting places, logistics, sharing services, etc. This concentration of functions offers enormous potential when it comes to reducing journeys and distances in everyday life. At the same time, a revitalisation of the surrounding urban areas can be achieved. In the future, the station districts will serve as a link between regional and international mobility axes on the one hand and city centres on the other.

6.2.4 Tourism – The City Centre as an Attraction

The touristic potential of the SOUTH ALPINE SPACE needs to be more effectively linked with inner-city attractions in the future. A focus should be put on creating attractive public transport services towards popular tourist destinations (e.g. skiing or hiking areas). Conversely, existing and planned tourist cycle routes should be integrated into the city centre mobility network in the best possible way. Moreover, a joint tourism brand identity focussing on sustainable and healthy tourism could be established. This would not only increase the number of overnight stays, but also lead to an improvement of the cooperation culture within the SOUTH ALPINE SPACE.

6.2.5 Building and Planning Culture – Reuse and Renew

A state-of-the-art building and planning culture must focus on the existing building stock. Considering the advancing climate crisis, it is crucial not to waste the grey energy stored in established structures. Existing buildings in many cases offer important qualities that only need to be restored or adapted in order to meet changing functional requirements. Therefore, ISEK⁴ sets the objective of securing, modernising and redensifying existing developments wherever possible. An active planning culture (architectural competitions, participatory and dialogue-based processes and citizen participation) offers the opportunity to develop tailor-made and location-specific solutions.

6.2.6 Planning for all Generations – Attractive and Inclusive

A holistic planning approach for the SOUTH ALPINE SPACE should aim to create attractive living conditions for local people - regardless of their age or circumstances. ISEK⁴ aims to achieve this objective through affordable housing for young families, students and pensioners that is tailored to local needs. Furthermore, childcare facilities should be improved, and the range of available leisure activities expanded. Thanks to the barrier-free design of public spaces, city centres will become easier to experience and enjoy for those with disabilities.

6.2.7 Regional Resources – Use and Expand

The interaction of complex global challenges (climate crisis, energy crisis, scarce municipal budgets, etc.) also has a noticeable impact at regional and local levels. The SOUTH ALPINE SPACE region has set itself the goal of focussing on regional or local strengths and potentials. A broad selection of high-quality regional products will help to increase the reliability of supply and the resilience in times of crisis. By expanding renewable energy production, the cities of the SOUTH ALPINE SPACE want to make a contribution to the efforts against the climate crisis. Tackling these challenges together as a region and agreeing on important core issues helps to relieve strained municipal budgets.

6.3 City-specific chapters of the ISEK⁴

The concept contains four local chapters for the four cities, which are then consolidated in the regional symbiosis to form an overarching joint development strategy in line with the holistic vision for the SOUTH ALPINE SPACE. The local ISEKs each include a situational assessment formulated as a personal experience report as well as an overview of current developments, existing concepts, and plans. The vision for the city centre in 2040 is presented graphically and through a future story from the perspective of a protagonist named Anna. Specific intervention plans have been developed for the so-called "focus areas", in which a

significant need for action has been identified (short to medium term). In addition, one so-called "perspective space" has been defined per city, a space that could be included in longer-term urban planning considerations.

Although all local ISEKs are aligned with common regional guiding principles, some strategic distinctions can be made. The Bruneck (South Tyrol) ISEK, for instance, places a particular focus on the integration of green and open space networks into the city centre and, more specifically, on increasing the attractiveness of the Rienz riverside surroundings. In Lienz (East Tyrol), strategic considerations focussed on opening up the attractive and well-frequented old town towards its surroundings while activating the "inner peripheries" around the centre. In the Carinthian city of Spittal an der Drau, which currently suffers from heavy traffic congestion along a major provincial road, the emphasis was on redesigning the city centre to promote active mobility. Finally, the local ISEK for Hermagor (also Carinthia) prioritises the reactivation and transformation of existing structures (e.g. an old backpack factory or a residential estate from the 1940s). The integration of these four individual local development strategies under a common regional umbrella has triggered interesting new dynamics and debates after the completion of the ISEK⁴ project. For instance, the newly constructed mobility centre in Lienz, which was frequently cited throughout the ISEK⁴ process as a best-practice example for linking active mobility with public transport services, has sparked discussions in other cities about redesigning station forecourts in a similar way.

6.4 Vision and regional symbiosis for the SOUTH ALPINE SPACE

Based on the results of the local workshops, a joint regional vision of the SOUTH ALPINE AREA was developed in collaboration with the local steering groups (Fig. 6). The illustration contrasts the physical spatial conditions by bringing the region's four city centres closer together graphically. This results in a region of short distances, in which the four cities are not only connected through collective activities, but also through (a rather fictional) spatial proximity. Local characteristics and individual potentials of the cities become just as visible as regional project proposals (e.g., a regional data cloud, the linking of tourism with public transport services or the expansion of supra-regional cycle routes).

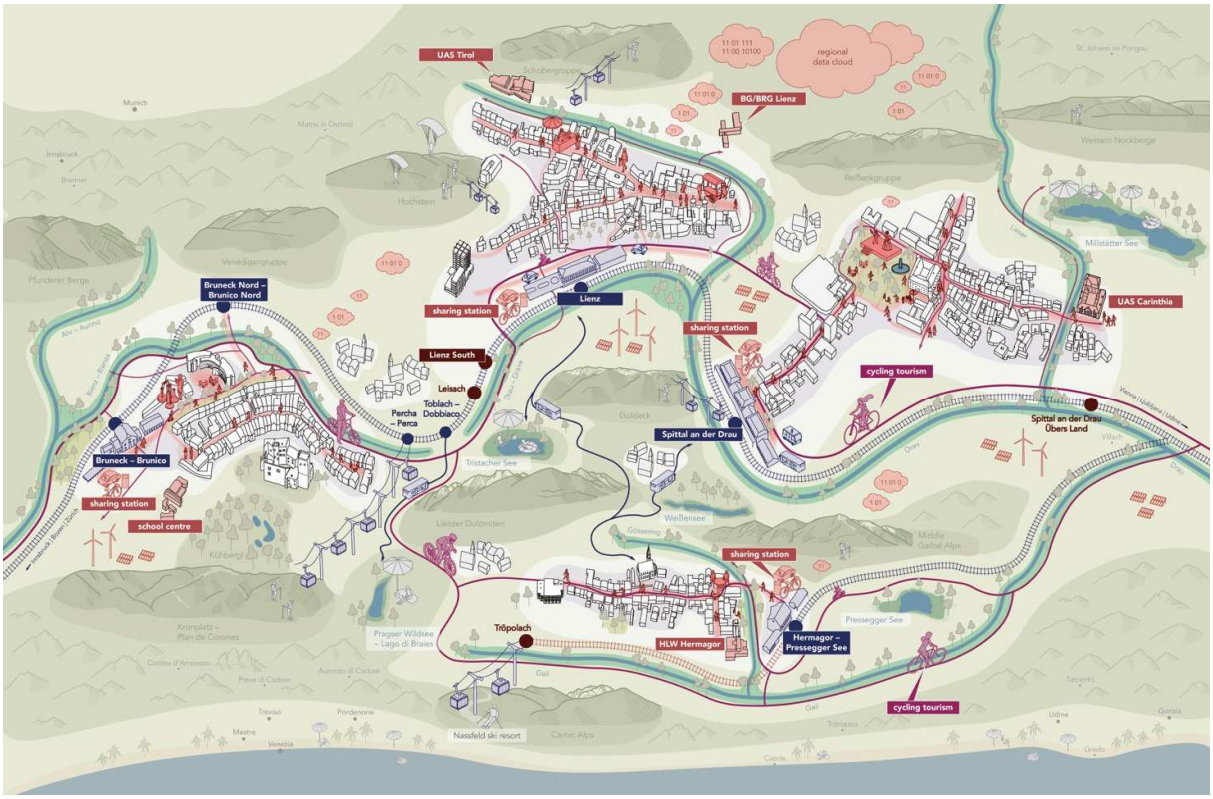

Fig. 6: Regional Vision

To accompany the graphical vision, a future story was developed using the storytelling method. The story, also written from the perspective of protagonist Anna, describes the SOUTH ALPINE SPACE as a well-

connected, future-orientated, innovative, and inclusive activity space. Excerpts from the future story (translated from the German original) are presented in the following:

It's a warm summer morning in 2040 and we meet up with architect Anna in a café near the mobility centre at Lienz train station. She is originally from East Tyrol and has studied at the FH Kärnten in Spittal an der Drau. After working in an architectural office in Milan for a few years, she returned to her native region just recently. Anna orders a cappuccino and tells us all about what has changed since she left for Milan: The SOUTH ALPINE SPACE has evolved to become an attractive, sustainable and inclusive region. The region takes particular pride in the fact that it has already been awarded the European Climate Label for Regions twice. One reason for this is that the railway has become the most important lifeline in the SOUTH ALPINE SPACE. Thanks to more frequent services and an improved mobility infrastructure, railway transport has almost completely replaced the private car. Today, the four inner cities are the driving forces of the region and represent key anchor points for regional co-operation. Anna takes the last sip of her coffee and invites us to accompany her for a day through the region. […]

Anna goes on to outline her everyday working life as a sought-after architect and takes the readers along on her train journey to her first job in Tröpolach near Hermagor.

[…] We arrive at the construction site, Tröpolach station, around noon and are cheerfully greeted by supervisor Sofia. "Ciao Anna", her voice can be heard reverberating across the entire platform. Anna returns the greeting and chats in fluent Italian with Sofia, who grew up in a small town near Cortina. The supervisor tells her that the new solar panels for the platform roofs have just been delivered. As soon as the modules have been installed, the station will be able to cover part of the electricity needs of the mountain railway to the Nassfeld mountain. […]

After finishing her tour of the construction site, Anna takes us back to Lienz, where the regional project marketplace will take place in the afternoon. In Lienz, the architect proudly shows the visitors the new "Ackerbox" at the railway station, a place where you can buy fresh products from around the region. The group proceed to the regional project marketplace by bike.

[…] Before the SOUTH ALPINE SPACE conference, Anna's friend Julia, an IT technician, presents her idea of an international, multilingual regional kindergarten offering full-time childcare. As a potential location, she suggests a vacant building near the NOI Techpark in Bruneck, right next to the central biodiversity park. Julia is obviously proud of how well the town has managed to combine local recreation with its focus on technology in recent years. She hopes that the public park will also be used as an open space for the new kindergarten – in her opinion, this would be the perfect way to combine playing with learning about biodiversity. The nearby Rienz river could also offer cooling on hot days. […]

Upon receiving a spontaneous call from her friend Daniel, Anna decides to spend the evening at an open air theatre event in Spittal an der Drau.

[…] We finally reach the city park. There's a lot going on here today – it feels like everyone in the SOUTH ALPINE SPACE has come to visit Spittal an der Drau. The open-air theatre performance turns out to be a great success and the sweltering heat under the palm trees in the city park has subsided a little. As we walk back to the railway station, we study the little flyer we were given in the city park on the way. The wealth of cultural events on offer in Spittal an der Drau is truly impressive. The train back to Lienz is well filled despite the late hour - apparently we weren't the only ones visiting from East Tyrol. This time around, we don't hop off at Lienz main station, but continue one stop further to the station near the "Südtiroler Siedlung", where Anna lives. She proudly tells us that she was involved in the redevelopment of the estate. The valuable historical building structures were renovated in the 2030s along with some densification work. Similar historic neighbourhoods in the other three cities were also remodelled based on the Lienz example. Thanks to the new station, the Südtiroler Siedlung has become one of the most popular residential areas in Lienz. At around 11 p.m., we say farewell to Anna at her front dook. She is tired, but already looking forward to the next day. […]

Beyond the regional vision, the regional symbiosis integrates the individual strengths of each city and the respective development approaches identified in the ISEK^4 process. The local and regional project ideas drafted during the local workshops were interlinked across the seven spatial guiding principles. This resulted in a project overview that reflects the most suitable scope for action in each case (individual city, bilateral or

trilateral co-operation or the region as a whole) and also shows possible synergy effects between the ideas. The regional symbiosis therefore demonstrates how the key spatial ideas could be realised in practice in the region.

7 CONCLUSION

Previous ISEKs in Germany and Austria have focussed exclusively on individual cities, specific districts or other spatially coherent urban structures. The key innovation of the ISEK⁴ project is the simultaneous consideration of multiple city centres within a regional framework. Through the symbiosis of four concepts, activities in the field of inner city development can be bundled synergetically and, in many cases, also implemented collaboratively. In line with the regional vision, in which the four city centres have clearly "moved closer together", joint projects could provide the momentum for a further deepening of the regional cooperation culture.

At the start of the work process, a conscious decision was made not to include the neighbouring municipalities in the concept - partly due to the time constraints of the project. In terms of an integrative planning approach, it would make sense to also include the needs and perspectives of the neighbouring municipalities in similar projects in the future. The question of what effects ISEK⁴ can be expected to have on the other communities in the region remains unanswered, but would be extremely interesting from a professional point of view.

The composition of the local steering groups varied from city to city and ranged from a purely political line-up to a mixture of representatives from civil society and politics. A precise recommendation on the optimal composition and size of the steering groups cannot be derived from the ISEK⁴ project team's experiences. Instead, the respective local planning and participation culture should be taken into account when forming the groups.

ISEK⁴ is not an implementation strategy and therefore does not contain any detailed or ready-to-implement projects. Instead, it contains sketches of initial ideas that could support the cities and the region in implementing the inner city development concept. The responsibility for detailed planning, political coordination and the implementation of specific measures now lies with the cities.

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🏆 *reviewed paper*

Latent Heat Storage to Improve the Urban Microclimate

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1 ABSTRACT

Whilst the world is trying to find a way without fossil fuels it still needs to find a possibility to switch heat or cooling capacity from times generated to times needed. This will even be more of interest when all energy needs are switched to electric generation and thus to renewable energies. Coming to this point, energy will be generated when available and be stored in between. Nevertheless, there will be a large difference in case of costs using energy when it is generated and when in abundance. Therefore, energy storage, especially for heat, will be indispensable in the future, in particular for places where lots of people live and large amounts of heat are necessary. Such storages can be made of phase change materials that store heat in the phase change from solid to liquid and vice versa. Thus, this paper expands on the current discussion on traditional phase change material for latent heat storage by innovatively suggesting salt hydrates. Based on explaining the principles of phase change material, the authors illustrate the application of salt hydrates resulted from experiments of the authors. In doing so, they differentiate between integrating phase change materials in active (i.e. in the water heat system) and passive heat storages (i.e. in the building structure). With these applications shown, which are either already available or necessary to be provided in near the future, an ecologically efficient improvement of the microclimate can be engineered.

Keywords: examples, latent heat storage, micro climate, benefits, experiments

2 INTRODUCTION

One of the most important challenges of the near future is the energy generation based on renewable energies. However, for this storages must be built on a large scale, and not only for electric energy but also for heating purposes (Mavrigiannaki and Ampatzi, 2016). Especially heating is thereby a major challenge because it is commonly based on fossil fuels which are a major detrimental effect on climate change and microclimate. Avoiding any combustion of fossil fuels, the future climate control of buildings will mainly be based on heat pumps. However, because of fluctuations in renewable energies and thus changes in the costs of electricity, heat generation will ideally be switched to times when these costs are less intensive, such as night times (Konuklu et al., 2015). This can be provided by using phase change materials (PCM) (Tyagi and Buddhi, 2007). Pointing to existing research gaps, Mavrigiannaki and Ampatzi refer to gain further knowledge on potential contributions of this technology in reducing carbon emissions (Mavrigiannaki and Ampatzi, 2016). Furthermore, authors called for further research on technologies and applications for specific alimates and building typologies. Based on a basic explanation of the functioning of PCM, experiments and practical applications of the PCM made of salt hydrates are provided in the following sections.

3 BASIC PRINCIPLE OF PHASE CHANGE MATERIALS

To store large amounts of heat energy in small volumes, it is reasonable to use physical phase changes, because the corresponding enthalpy is much larger than just a change of temperature (Khudhair and Farid, 2004). Furthermore, the operating point is fixed through the melting temperature, and thus the application has not to be appropriate to a steady increase or decrease in temperature, for example. This is underlined by the number of papers dealing with phase change materials that were published between 2011 and 2019 (Mustapha et al., 2021). The number was steadily increasing, especially in China, the United States of

America, and Germany. This is due to legislative changes in these countries and to state fundings that were granted.

The whole physical effect of phase change materials is similar to using ice cubes to cool down drinks or to a so-called hand warmer used during the skiing season. The storage material can thereby bridge the time between energy generation and consumption and therefore reduce any energy wastes or process inefficiencies (Konuklu et al., 2015; Kabeel et al., 2017). Especially when the process implementation must have a constant temperature, this kind of material is more appropriate to be used instead of a large water storage, for example. For the future this will even be more important when the energy generation is based on renewable sources and the ongoing climate change is considered because excess energy can be stored and used when needed avoiding unnecessary efforts or useless large storage designs (Rouault et al., 2016).

A known disadvantage, so far, were the material costs, hence the small amount implemented in building structures. This can be avoided using salt hydrates with a phase change enthalpy of a minimum of 80 kWh/m³ instead of paraffines being chemically and toxically harmless and inexpensive enabling the integration of large masses into the construction (Sonnick et al., 2018). The principle of phase change materials is shown in Fig. 1. With sensible heat, a material can be heated or cooled down, but it is connected to a change of temperature. Whilst during the phase change, the temperature is kept similar and, usually, significantly more energy can be stored during this step, because no large temperature changes are typically desired.

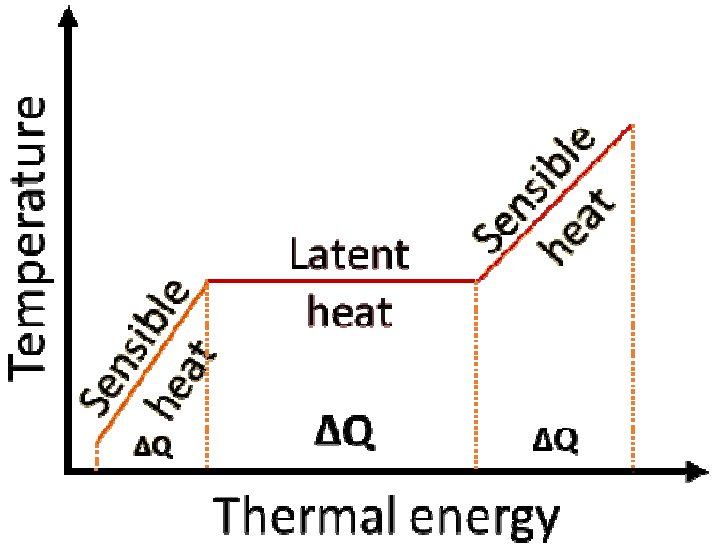

Fig. 1: Typical temperature curve of a phase change material.

Following are some applications shown, which are either already available or are interesting for the future to efficiently improve the microclimate ecologically.

4 BUILDING CLIMATE CONTROL

As already explained, in the future will be more distinguished between times when heat is generated and used. During nighttime most people do not use heating, therefore it has to be stored until times when it is needed. Thereby, it can be differentiated between active storage included in the water heating circuit and passive storage included in the building structure.

4.1 Active PCM integrations

As shown in Fig. 2 two different integrations of active storage PCM in the water heating system are possible. One is to extend the heat storage capacity of the water tank by adding PCM to the wall or by putting it directly into the water tank whereby it has to be macroencapsulated (left pictures). This system can also be used to store heat during the day from a solar thermal system for showering in the evening and simultaneously melting the PCM. During nighttime, the PCM is heating the water again providing warm water in the morning time. In Fig 2. on the right side a different system is shown. An additional heating

liquid circuit is installed which is not soluble with the PCM and thus can change heat via direct contact (Kunkel et al., 2018, 2020). The thermal liquid can be heated by solar thermal energy thus melting the PCM. Switching the thermal liquid circuit to another heat exchanger which is flushed with the water heating circuit of the building, can provide warm water for several applications within the building. For these applications, PCM with a melting temperature of about 56 °C should be reasonable. (Kunkel et al., 2019)

Fig. 2: Examples for active storages in the water heating circuit.

4.2 Passive PCM storages

Another possibility to store energy is to integrate macroencapsulated PCM within the building wall or roof as a passive system. However, in this scenario, it is necessary that the PCM can remain there for the lifetime of the building and still perform. Key advantages of this system are that no additional space has to be kept clear and that no further energy is necessary. If the sun is warming the outer wall the PCM will start to melt and therefore keep its temperature not warming the living rooms up until the whole PCM is melted. During nighttime when the temperature drops to a lower point than the phase change temperature of the PCM, the PCM begins to crystallize and will again keep the room temperature stable until all the PCM is crystallized. This kind of system with wall installations is shown in Fig. 3. Thereby, the PCM is installed double-layered to realize ventilation between the packages and to improve heat transport. Measurements with PCM with a melting point of 21°C were performed against another room with no PCM showed a reduction of the day/night temperature fluctuation of 62 % and an overall reduction of the fluctuation of 57 % against the reference room. (Sonnick et al., 2020)

Fig. 3: Macroencapsulated PCM within the building wall with space for ventilation

In Fig. 4 PCM (21 °C) integration in an intermediate ceiling and in floor compartments of a tiny house is shown. The results showed a reduction of overheating during summertime and a more stable temperature during nighttime when the outside temperature dropped (Sonnick et al., 2018). This was especially significant because this tiny house is made of wood and thus has a low heat storage capacity by itself. Therefore, PCM can affect the temperature stabilization of buildings as well as increase the overall heat storage capacity especially when it is built out of wood or other light materials.

Fig. 4: Macroencapsulated PCM integrated in the floor compartments (left, middle) and in the intermediate ceiling (right).

4.3 PCM integration in concrete

Besides aforementioned examples, PCM can also be integrated within concrete walls or blocks. Thereby, the shape of the PCM together with the macroencapsulation is of main importance to achieve the best heat transfer (Erlbeck, Schreiner, Fasel, et al., 2018; Erlbeck, Schreiner, Schlachter, et al., 2018). In Fig. 5 two concrete blocks were produced whereby one was filled with a macroencapsulated PCM package (right block). Both concrete blocks were left in the sunlight to warm up. As can be seen, the concrete block with PCM takes more time to increase the temperature. It is imaginable that such tiles can be used to build a terrace at home as well as to decrease the overheating of cities by installing such tiles for sidewalks within the city center or at a place where it is expectable that the sun will warm up the floor.

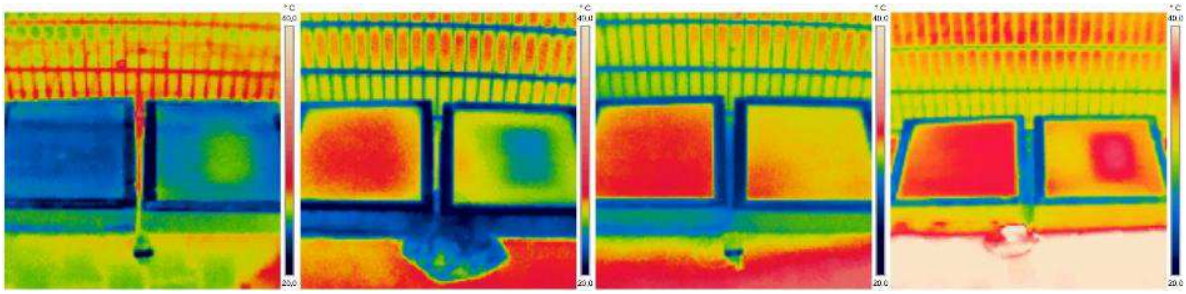

Fig. 5: Macroencapsulated PCM integrated in concrete blocks and heated by sunlight.

An exemplary temperature profile of these tiles can be seen in Fig. 6. The tile without PCM overheated quite more than the tile with PCM. The same effect did happen when the outside temperature was lower but is unfortunately not visible in the profile. Nevertheless, the tile with PCM kept the heat longer and did therefore cool down more slowly with a higher negative peak temperature than the tile without PCM.

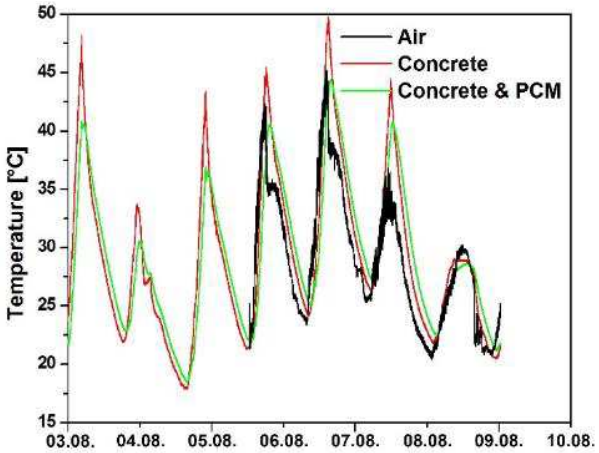

Fig. 6: Temperature profile of concrete tiles with and without PCM inside left outside in the sun.

4.4 PCM integration in furniture

Besides direct integrations into the building structure, PCM can also be integrated into design elements or furniture. In Fig. 7 some examples are shown. Two park benches were made, one of wood and one of concrete. The wooden one was filled with PCM packages and a ventilation system, whereas for the other bench, the PCM was cast in concrete improving the heat transfer via direct contact. Furthermore, several concrete columns were fabricated and integrated into the offices to improve the climate within the rooms.

Fig. 7: Several PCM integrations into furniture made of concrete or wood.

4.5 PCM for floor heating

Newly built houses tend to have floor heating, which per se does improve the energy efficiency of the building but also allows to use PCM directly within the piping system of the floor heating. However, normal PCM is not pumpable, especially in the solid phase, therefore, it is necessary to mix it with a thermal liquid. Both materials must not be soluble with each other. With the correct concentration of PCM and thermal liquid, the suspension can be pumped through the whole floor heating as well as through the heat exchanger through which the PCM can be charged by solar thermal energy, for example. Nevertheless, it is necessary to mix the solid PCM with the thermal liquid in advance, and this with the help of a disperser, so the crystals have the correct size to not only block any pipe but also to ensure a fast heat transfer. This system helps to keep the complete floor at a constant temperature level which will increase the overall efficiency of the heating system even more keeping the condensation temperature of the heat pump as low as possible. Furthermore, the same installation but in the room ceiling, combined with a PCM with a melting temperature of about 21 °C, in contrast to the heating system where the PCM should have a melting temperature of about 30 °C, could keep the room cool during summertime. Such phase change systems can be found in the scientific literature, and they are called PCD for phase change dispersions. The difference between a normal crystal growing in another fluid is shown in Fig. 8. As can be seen in the upper picture there is a large crystal pointing in the direction of pumping. Whereas the picture below shows lots of small particles evenly distributed. These small particles make sure that the pipes and if used the static mixer are not blocked, that the dispersion still has the properties of a fluid, that the heat transfer is as large as possible, and that usual installations can be used.

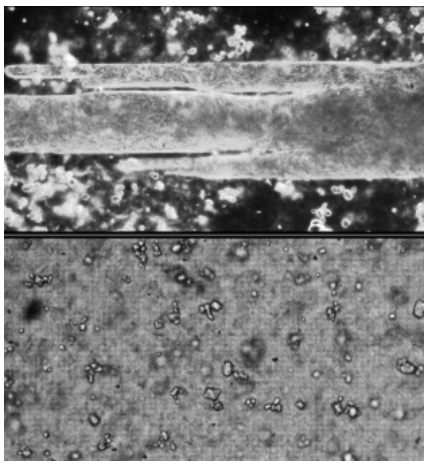

Fig. 8: Normal crystal growth in the direction of pumping direction (upper picture) and a PCD with small crystals evenly distributed (lower picture).

5 FURTHER APPLICATIONS

In a modern city, more applications of PCM are possible and will have an impact on the quality of life. If available a district cooling system can be used to cool down buildings during summertime. The water storage, which is feeding the grid can thereby be increased in case of stored energy when a large amount of PCM is included in the tank. The storage can then be charged during nighttime when the electricity costs are neglectable, and the cold can be used during daytime. As PCM, water or a salty water solution can be used to have a melting point at 0 °C or below, or a PCM with a melting point between 10 °C and 0 °C is usable. Which PCM will be used is dependent on the grid, the customers, and thus the electric effort for cooling.

Another cooling possibility is delivery trucks which drive mainly in the region of a city but no large distances. Such vehicles delivering food or medicaments for example will in future all be driven by electric motors and thus should have no climate machine onboard. Therefore, the cooling load must be sufficient enough for a whole tour through the city. This can be realized by optimizing today's cooling vans by integrating PCM within the vehicle wall to increase the overall heat capacity of the loading area. In Fig. 9 a cooling truck is shown which was simulated to show how long the cooling process would take place when the door is opened and PCM within the wall has to take up the incoming heat to keep the goods chilled (Gaedtke et al., 2020).

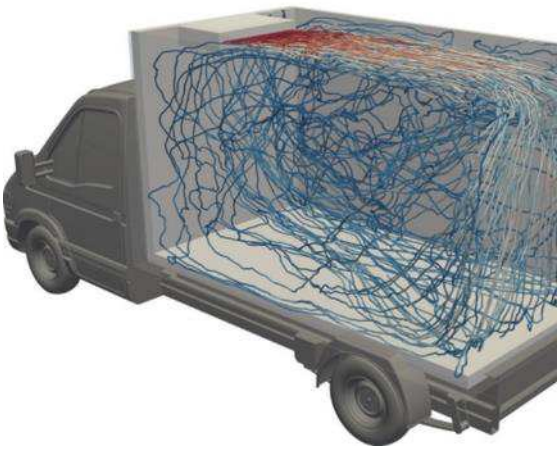

Fig. 9: Simulated flow elements within a delivery truck.

6 CONCLUSIONS

As shown in the previous text are several PCM applications already realized in use, but more is possible and will be implemented. All these options will help to control the microclimate within a city or the building itself and thus will make places more worth living at, even with ongoing climate change. Materials are developed and completely available. Furthermore, there are lot of applications where such materials can be

incorporated and improve the energy management of a city or industry within a city. The potentials just have to be identified and realized.

PCM can thereby integrated within the building structure or in heating or cooling systems to increase the heat storage capacity, especially of buildings with a low thermal storage capacity as wooden houses. With cheap salt hydrate as phase change material design elements can even be produced controlling the climate within an office or keeping sidewalks cool during the day and pleasant warm during the night. Replacing combustion engines with electrical motors will lead to a reconsideration of what is really necessary and must be transported or not. This can change the designs of cooling trucks for example. PCM can be included within the vehicle keeping the goods chilled as long as the truck is on its way and can then be recharged when back at the docking station.

These examples show the whole options that are thinkable from the perspective of inhabitants, company owners, and city officials. However, it is inevitable that all these stakeholders come together to build resilient cities for the future.

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🏆 *reviewed paper*

Maintaining Water and Sanitation Service Delivery in Rural and Peri-Urban North West Province of South Africa: Governance as Social or Entrepreneurial Responsibility?

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1 ABSTRACT

Globally, the success of municipal governance is measured by effectiveness towards service delivery, which is evident in quality and accessibility by residents. Primarily as a social service, there is a prevalence amongst metropolitan governments globally to impose rates or privatise service delivery. Although a middle-income country, South Africa is considered one of the most socioeconomically unequal societies in the world. To balance the socioeconomic disparities, South African municipal governments provide basic services such as water and sanitation without exerting rates in rural areas and most peri-urban communities. Given recent economic downturns, growing population and increasing urbanisation, among other adverse factors, South African municipalities struggle to ensure efficient service delivery. This article contributes to studies on effective municipal service delivery models. It case studies North West Province of South Africa using qualitative methods involving interviews and desktop reviews of social and market theories. Preliminary findings reveal a dilemma in the iteration of neo-liberalist ideals within the context of welfarist manifestoes and the economic question of profit-making against welfarism. The study recommends regular tax eligibility assessment for residents of periurban areas who are currently outside rate-paying delineated areas. The process of infrastructure development and service delivery requires huge financial resources. Reliable service delivery and quality infrastructure to improve quality of life are the epitome of good governance, ensuring equitable societies and guaranteeing economic growth.

Keywords: Service delivery, infrastructure, municipalities, South Africa, planning

2 OVERVIEW

2.1 Introduction

Municipalities or local governments have the duty of delivering basic services to their inhabitants (Rosalie et al., 2020). Frost (2014) identifies five fundamental service delivery functions of local governments necessary for proper functional societies. These services are water supply, waste management, transportation, electricity and sanitation. Other services might include security (police services), primary education, health care and food safety inspections. These services may be provided either via a municipal agency or by subcontracting to a third party. What is termed “basic service” are services that guarantee community members' health and safety (RSA, 2010). Nevertheless, municipalities are responsible for ensuring the enhancement and accessibility of services to people, even if they are unable to directly provide such services. Municipalities have the option to transform service delivery process into corporations or delegate the provision of services to other municipalities, organisations, or private firms (Tavares, 2017; Ferry et al., 2018). Financing for the services provided is contingent upon municipalities and may include tax money, fees, grants, and penalties. Municipalities are responsible for overseeing the delivery of services and managing the establishment and modification of fees by the service provider for the municipal service.

The provision of municipal services is crucial in influencing the standard of living of residents (Ilinykh, 2020; Boguş, 2022). Optimal and impactful provision of municipal services is essential for cultivating sustainable urban growth, advancing societal welfare, and guaranteeing economic success. Municipalities often have fiscal limitations, which restrict their capacity to allocate funds towards infrastructure and service delivery enhancements. This is also linked to population growth, which puts pressure on existing infrastructure, such as housing, transportation, and utilities. Financial constraints may undermine the quality and extent of vital services, impacting the overall welfare of metropolitan areas. This contributes to

antiquated infrastructure, inadequately maintained roads, and insufficient public amenities, which impede the delivery of vital services. This study evaluates issues emanating from municipal service delivery provisions in North West Province of South Africa. These issues pose obstacles to efficient service delivery, which raises questions about municipal governance as a social or entrepreneurial responsibility. Municipal services examined in the context of this study are water, sanitation, and transportation.

2.2 Study Objective

To examine the implications of service delivery as a social or entrepreneurial responsibility of government.

2.3 Methodology

The article is a qualitative study utilising desktop reviews and ten expert interviews conducted between May and October 2022. The role of South African municipal governments in service delivery is examined from the prism of the Austrian school of economics and the political economy through the review of social and market theories. These have extensively studied entrepreneurship and conducted economic analyses of institutions, which form the basis of the literature review, which provides the framework for the analysis of findings and discussion. Also examined are the legal framework documents guiding municipal service delivery in South Africa, such as the Municipal Structures Act 117 of 1998, the Municipal Systems Act of 2000, the Municipal Infrastructure Grant, and the Traditional and Khoi-San Leadership Act 3 of 2019.

3 LITERATURE REVIEW

In this study, we examine the role of governments as the umpire for the economy and service delivery through the lenses of the Austrian School of Political Economy. For Austrian political economy scholars, analysis of market inventions by governments is critical to understanding social phenomena (Milonakis and Fine, 2009; Kornberger et al., 2018). According to Mises (1949), the market is a social entity and a cornerstone of society whose outcome results from the people. Moreover, it is acclaimed (ibid) that the market is not defined as a tangible place, an item, or a collective entity. The market is a dynamic system propelled by the interactions of individuals who cooperate within the structure of the division of labour. In Austrian political economy scholarship, the market is a social structure or a spontaneous order that emerges from the acts of people competing for resources and collaborating in providing and distributing products and services (Ikeda, 1994; Jackson, 2019).

The emphasis and essence of the market manifest in capitalist societies, which, according to Lefebvrian analysis, emanates from the space of work and consumption (Moreno, 2014; Cunningham, 2019). In classical economics, Karl Marx, in laying the foundation of central planning, sought to solve the persistent contradictions between the public and private societal spheres (Healey, 2020). In this, he argues, the public sphere (the government) will ultimately get drowned in the bidding of the private sphere bound by competition. As such, the competitive market was to be scrapped to replace controls in the public sphere. Scholars adjudge this utopian framework - a societal framework aimed at perfection, but it might never happen (Lavoie, [1985] 2016).

The private sphere branded by capitalism is driven by maximising profit as the primary aim before considering the service provided. Relatedly, quality service delivery is directly proportional to increased cost. As custodians of the public sphere, governments also regulate the market and the private sphere. Ludwig von Mises developed the notion of interventionism in the 1920s to delineate the amalgamated economic system that arose after World War I (Vahabi and Mohajer, 2020; Kolev, 2021). According to his perspective, interventionism is an intrinsically precarious strategy since it generates fresh disruptions that seem to need other interventions, which, in turn, fail to resolve the issue. The cessation of interventionism leads to socialism, a destiny that can only be rationally averted via a decisive shift towards free markets. Mises cautioned that mixed systems engendered political volatility and economic inertia and substantiated this assertion via a comprehensive framework of interventionism and a meticulous examination of credit expansion, subsidies, welfare, corporatism, and the war economy. Interventionism refers to the practice of a social authority imposing restrictions on the use of means of production by enterprises and owners (Von Mises and Greaves, 2011). Mises regards taxes as a kind of interventionism, especially when employed by governments as a tool for cross-subsidisation or instilling socioeconomic justice.

Social justice, which entails redistributing resources to rectify economic disparities, is often seen as incompatible with a free society that is defined by market institutions and a limited government that promotes norms of equitable conduct (O'Neill, 2020). These claims emerge from the acknowledgement of systemic inequalities that people encounter as a result of the structure or operation of society. Several assessments of underdeveloped economies neglect to include the essential contribution of the "protective tier" of entrepreneurship, which plays a major role in economic activity in the developing world. Entrepreneurship has a vital role in enhancing economic performance when the institutional setting is conducive (Baumol, 1990; Boettke and Coyne, 2003). Entrepreneurs, motivated by the appealing opportunity to increase economic profits, rearrange economic resources to what they see as more significant and efficient objectives. Societies exhibiting a high degree of entrepreneurial activity and low levels of unemployment are more likely to establish a larger number of businesses to capitalise on possible profits in the immediate future (Lucas et al., 2018). Ultimately, nations that own more sophisticated tangible resources and allocate more resources towards human capital will see more economic progress.

4 CONTEXTUAL DISCUSSION

The North West province is located in northern South Africa, next to the Botswana border. The Kalahari Desert borders it to the west, the Gauteng province to the east, and the Free State to the south. The Province spans over 104,882 square kilometres and is inhabited by a population of 3,748,436 people (BPDM, 2021). The majority of the Province is comprised of expansive plains adorned with sporadic vegetation, including trees and grassland. The Vaal River traverses the southern boundary of the Province. Mahikeng, formerly known as Mafikeng, serves as the capital city. The Province comprises 18 Local Municipalities within four district municipalities, namely:

(1) Ngaka Modiri Molema District Municipality

(2) Bojanala Platinum District Municipality

(3) Dr Kenneth Kaunda District Municipality

(4) Dr Ruth Segomotsi Mompati District Municipality

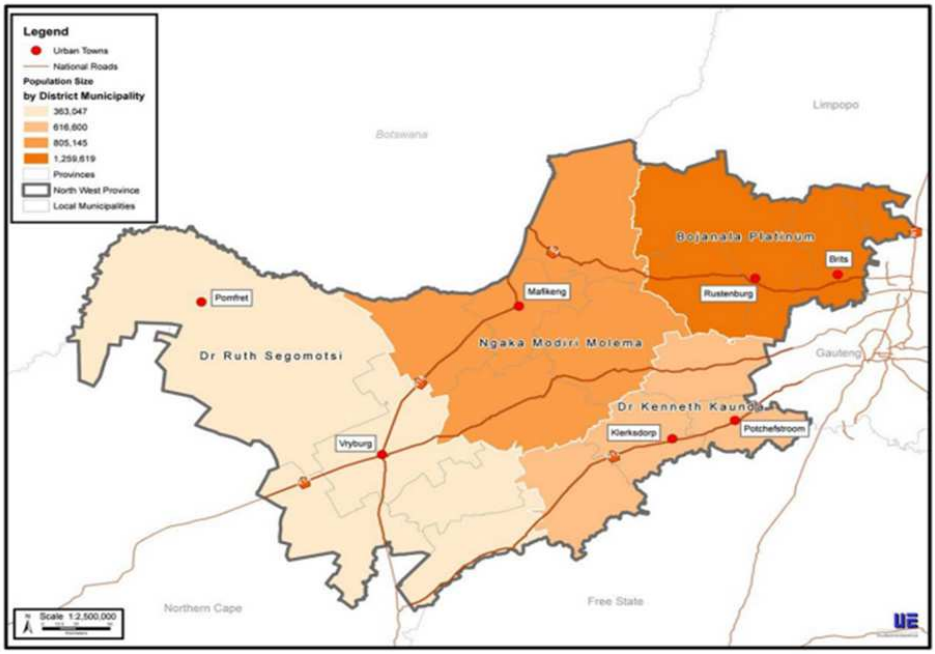

Fig. 1: Map of North West Province Showing the District Municipalities. Source: (Bojanala Platinum District Municipality (BPDM), 2021).

5 LEGAL FRAMEWORKS FOR MUNICIPAL SERVICE DELIVERY IN SOUTH AFRICA

Municipal governments are responsible for service delivery, albeit within the national government's regulations. This is an enshrined Constitutional provision mandating municipalities to "ensure the provision of services to communities in a sustainable manner," according to Section 152(a) (b) of the 1996 Constitution (RSA, 1996). There are three delineations for South African municipalities: metropolitan,

district and local municipalities. Also, eight metropolitan municipalities cover the large urban conurbations around South Africa. Other parts of South Africa are delineated into local municipalities, which are further grouped under district municipalities. The rationale for the delineation is to facilitate development and service delivery in rural and grassroots communities. Within the context of this study, there are no metropolitan municipalities in North West Province, implying an overwhelmingly rural and low-intensity urban development.

According to the South African Guide for Municipal Infrastructure Service Delivery, South African municipalities are mandated to provide the 'most immediate needs' of society, which should be universally accessible to meet national developmental targets (COGTA, 2010). These services include sanitation, water supply, health centres, roads/stormwater drainage, electricity, solid waste disposal, and sports facilities (ibid). Municipal Systems Act no 32 of 2000 allows municipalities to generate income through taxes, rates and levies (RSA, 2000). As such, maintenance of the infrastructure for basic services comes through tax revenues and rates. In the broader scheme of national strategic planning, South Africa's municipalities are mandated to produce Integrated Development Plans (IDPs), a five-year tenured strategic planning document. These IDPs are expected to align with current national and provincial strategic plans. Within this strategic planning document, municipalities can access municipal infrastructure grants which would be based on strategic quotas and development benchmarks.

Municipalities are expected to respect the Constitution's provisions, ensuring that every member of the local community has access to at least the bare minimum of fundamental municipal services, according to section 73(1c) of the Municipal Systems Act No.32 of 2000. Under Section 74(2c) of this Act, "life-line tariffs" for limited service usage are to be imposed to pay for the provision of vital services to low-income households (RSA, 2000). The plan must cover low-income homes that cannot pay for basic sanitation services, per the legislation. For example, the national government established the Free Basic Water Policy in 2001. Due to the water shortages, this strategy advises the government to give 6000 gallons of water (or 25 litres per person) every month (DWAF, 2007). According to the Act, cross-subsidisation must be used to pay for the cost of this service. To address the legacy of apartheid and historical inequalities, the Water Law Review Process, which replaced the "White Paper," and Sections 24 and 27 of the 1996 Constitution [Act No. 108 of 1996], are being used to cover the costs of poor consumers by the wealthy who frequently consume and occasionally waste enormous amounts of water within municipalities.

6 FINDINGS

The Municipal Infrastructure Guide prioritises basic service delivery to rural areas (COGTA, 2010). However, the cost of service delivery to rural areas is often higher than that of urban areas, primarily due to low-income levels. According to the national policy frameworks guiding municipal operations, district municipalities provide water and sanitation services, while local municipalities provide other basic services. However, findings note that most local municipalities lack technical and human resources to administer their functions. In these cases, district municipalities provide capacity support to local municipalities under their jurisdiction. Associatedly, due to sparse infrastructural presence in rural areas, the cost of providing basic bulk infrastructure is usually higher. Inefficiency in municipal service delivery is a noticeable trend amongst municipalities in North West province. It is asserted that there are marked inequalities in service delivery based on the comparison between rural and urban areas within the province. Conversely, with the presence of customary administration within the Province, these form parallel or dualist governance, entrenching a dichotomy between municipal and customary authorities.

Intriguingly, the presence of mining activities and the capacity of customary authorities hosting mining activities to collect royalties from mining companies have financially empowered customary authorities to provide their communities with water supply, roads, stormwater drainage and schools. These are accessed by communal residents free of cost. However, customary authorities lacking mining activities cannot wade into service delivery provisions for their residents. The foray of some customary authorities raises questions about their constitutional roles. Essentially, the Traditional and Khoi-San Leadership Act of 2019 permits customary authorities to enter into developmental agreements with mining firms, corporate agencies, and municipalities (RSA, 2019). Some customary authorities are accused of drafting development plans independent of municipal IDPs, thereby duplicating and making the service delivery efforts of municipal authorities redundant. Nevertheless, the foray of some customary authorities into basic service delivery has

accelerated rural development, highlighting the disparity between rural communities without mineral resource exploration.

Municipal authorities in North West Province are able to exert rates within the urban core or essentially areas without customary land claims. Due to expanding urbanisation and the impact of defunct apartheid land policies, several customary administered lands now lie in periurban locations within the Province. There are noticeable imbalances in service provision between customary and municipal-managed regions, partly linked to tax evasion by residents. It is acclaimed that there is a growing inclination among individuals to live in peri-urban regions under the jurisdiction of customary authorities to evade payment of city rates. This is because customary administered areas (rural and periurban areas) are not subject to charges such as tenement/land use fees and council taxes. In addition, the Municipal councils provide complimentary water and sanitation services to rural and peri-urban regions, often under the authority of traditional authorities. There is a growing trend of individuals choosing to reside in customary administered lands in peri-urban regions to avoid paying local government fees. This leads to an excessive burden on the social infrastructure in these areas.

Furthermore, the absence of municipal rates in customary administered areas, particularly peri-urban areas, significantly contributes to the loss of municipal revenue. Mosiane View is an example of a sprawling settlement in a customary managed territory and a periurban location – a suburb of Mafikeng, the provincial capital of the North West Province, under the Barolong Boo-Ratshidi traditional council. Inhabitants of this area choose to reside in this location to evade municipal taxes and regulations while accessing the amenities and opportunities offered by the Mafikeng metropolitan centre. On the other hand, there is increasing discontent with how municipal services are provided, and the public's level of satisfaction is so low that they do not feel motivated to fulfil their civic duties by paying municipal taxes. In 2021, the inhabitants of this community strongly opposed the efforts made by the Mahikeng Local Municipality to elevate the community's status to that of a township. This would include implementing city regulations in the settlement. The dilemma arises for municipal authorities to win periurban residents' trust to ensure good service delivery from residents' taxes.

7 DISCUSSION

Between 2016 and 2019, South Africa's population grew by 5% from 56.02 million to 58.78 million, within a marked rural-urban population drift and sprawling periurban developments, which evidence population growing beyond the provision of basic service delivery (Adom and Simatele, 2022). This impact on rural development means a rapid investment to boost service delivery infrastructure to reverse the emigration trend. The ANC-led national government, through its free basic policy, especially in water supply, aim to entrench social justice to resolve apartheid-inherited socioeconomic disparities. While this strategy of restoring socioeconomic parity has positively impacted rural development, it has created a revenue leech in periurban areas wherein residents depend on municipal services without owing responsibility to pay rates. The concept of social justice in Austrian economics applies to understanding the redistribution strategy and equitable service access in South Africa's municipalities. As with interventionism defined in Austrian economic thought, cross-subsidisation as a water policy socioeconomic equality strategy means the taxation of urban areas to subsidise rural communities' service delivery needs. However, as findings from this study reveal, residents of periurban areas also latch on to the benefit of cross-subisdisation to evade possible council rates. This tacit subversion of free market entrepreneurship makes progress towards good service delivery precarious, affecting the quality of service delivery. Entrepreneurship, despite the penchant for profiteering and subversion for social justice, ensures socioeconomic growth through increased productivity and associated job provision. Rural development programmes that might include cottage industrialization are related to increasing economic productivity and improving residents' socioeconomic welfare. This encourages entrepreneurialism, and there will be a need to implement the imposition of rates as an interventionist measure to control tendencies of excessive profiteering.

8 CONCLUSION

The interaction between the provision of service delivery and residents' access to quality service delivery was discussed from the social and market theories framework. The low-intensity urban development in North West Province, coupled with the presence of customary administrative structures, compels the provision of

free water and sanitation services by municipalities and, where possible, by customary authorities. This has entrenched welfarist-socialism with failing quality service delivery as population growth pressures shift to periurban districts. As the provision of service delivery is entrepreneurial, the framework for municipal service delivery has sought to minimise capitalist intent through redistribution. On the other hand, the enhancement of the entrepreneurial capacity of service delivery agencies can be related to economic growth from the generation of funding through rates leading to efficient service delivery and, by extension, the creation of more economic opportunities. From the noted growing trend of rate evasion of periurban residents, there is a need for tax evaluation so that the tax burden for cross-subsidisation is not enforced on just a few residents.

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MELT Plates: The Abolition of Overheating in Lightweight Buildings through an Optimised form of Latent Heat Storage

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1 ABSTRACT

The predominant form of construction of residential and commercial buildings in the Federal Republic of Germany and other industrialized countries is that of solid construction. However, increased public awareness of the need to reduce CO_2 emissions is resulting in questioning this classic way of constructing buildings as the immense energy consumption in the production of cement and concrete makes the search for alternative designs indispensable. Alternative building methods with lower CO_2 impact are lightweight construction methods like prefabricated wooden buildings or even container-based buildings. One disadvantage of such buildings, even though they often are very well insulated, is their low thermal storage mass and, thus, that they overheat in summer and cool down quickly in winter, provided there are no constant sources of cooling or heat available. Technically this constant energy sources would be available in most of the cases, but as we want to use renewable energy sources, which are only available on a fluctuating basis, a thermal storage effect of the building itself is of primary interest.

This paper presents the benefits and limits of so-called MELT Plates, a newly developed method of the startup MELT to apply latent heat storage technology in buildings significantly contributing to micro climate improvement, and practical applications based on relevant experimental methodologies applied by the authors.

MELT's products will make a decisive contribution to the heat transition. The previously very cost-intensive niche product "phase change material (PCM)" will become more user-friendly and significantly cheaper thanks to technical innovations and can, therefore, open up the mass market. The initial application addressed is increasing the thermal storage capacity of lightweight buildings by installing the materials in the building envelope. This serves as overheating protection in summer and in winter, through a combination with photovoltaics and/or dynamic electricity tariffs, an even more ecological and economical heating system with heat pumps is made possible. Thanks to their adaptability, MELT products are also ideally suited for numerous other applications, such as the intermediate storage of heat in industrial processes.

Keywords: overheating, climate change, temperature conditions, heat storage, prefabricated buildings

2 BENEFITS AND OVERCOMING PREVIOUS SHORTCOMINGS

2.1 The Functioning of MELT Plates

Whilst the CO2 footprint is already reduced in wood-based pre-fabricated houses, further CO2 savings are suggested by turning to modular, scalable container construction. However, the disadvantages of all types of construction with lower mass are related to the lower thermal inertia, which means that the buildings heat up more quickly to above comfortable temperature and also cool down again quickly. This unfavorable circumstance can be counteracted by a new dosage form of so-called latent heat storage, which thermally stabilizes at exactly the melting temperature. Latent heat storage uses the solid/liquid phase transition of selected materials to deposit heat and cold. In contrast to water or ground heat storage, the temperature does not change when energy is added or released, hence, granting for a sustainable, continuous power supply (Saha et al., 2021). This method is regarded to fill the gap between demand and supply inherent in inefficient energy systems (Jouhara et al., 2020). In the past, many authors have investigated and published interesting

applications for phase change materials in buildings in a scientific context (Liu et al., 2022; Reddy, Ghazali and Kumarasamy, 2024; Baylis and Cruickshank, 2023). Most investigations showed very good results from an energy point of view. The authors of this publication have published several promising studies on the use of PCMs in buildings (Sonnick et al., 2018; Sonnick et al., 2016; Sonnick et al., 2020). In Sonnick et al. (2020), for example, a reduction in day/night temperature fluctuations of 62 % was achieved in a lightweight prefabricated house using phase change materials as a natural cooling in summertime. In addition to applications in the building sector, the materials can be used, for example, in electrically powered refrigerated vehicles to increase their range (Gaedtke et al., 2020). Solar heat can be temporarily stored in heating buffer tanks (Kunkel et al., 2019; Kunkel et al., 2020) and, in the transportation sector, temperature-sensitive goods, such as food or medicines, can be safely shipped using PCMs. Even though scientists agree on the effectiveness of PCM, no product that is specifically designed for use in buildings has yet been able to establish itself, particularly from an economical point of view.

Furthermore, the previous disadvantages of this storage medium were addressing ecological concerns, fire load, poor heat transfer and a lack of quantitative scalability.

To overcome these shortcomings, the start-up Melt has now developed a device that is optimal for equipping buildings with low mass: the MELT-Plate.

The panels can be manufactured in big quantities by machine but can also be adapted to specific shapes. Due to the plate shape, it offers a big surface area and, therefore, good heat transfer even with small temperature differences to the surroundings. Representing a further advantage, the plate can be subsequently integrated into the building structure, even in existing or old buildings, e.g. in attic apartments. Hence, Melt-Plates, consisting of sustainable material, could be integrated into a holistic, sustainable energy concept during construction (or renovation). The combination of the MELT- Plate, which corresponds to the norms and regulations/specifications that come into force, with the well-known renewable energy sources will increase the overall efficiency of the house/building.

The MELT Plates were developed in dialog with industrial users and tailored to their needs - e.g. in terms of flexibility, mounting simplification and unit costs. The possible positioning of the MELT Plates in buildings was developed together with the prefabricated house builder “Willi Mayer Holzbau GmbH”. In the case of wall mounting, the MELT Plates are installed behind the mounting level for the classic supply lines. This greatly reduces the risk of damage. When combined with underfloor heating, the flat MELT Plates are arranged in the floor structure below the heating mats. The adjustment of the melting point to the flow temperature of the heating system leads to a considerable increase in the efficiency of the heat pump. Underfloor heating systems and MELT Plates, therefore, complement each other perfectly.

3 PHYSICAL BACKGROUND AND STATE OF THE ART

Phase change materials (PCM) are materials that melt or solidify during use and, thus, by utilizing the heat of fusion, have an enormous storage capacity at a constant temperature. Figure 1 shows the temperature curve of a PCM compared to a sensitive storage material without phase change.

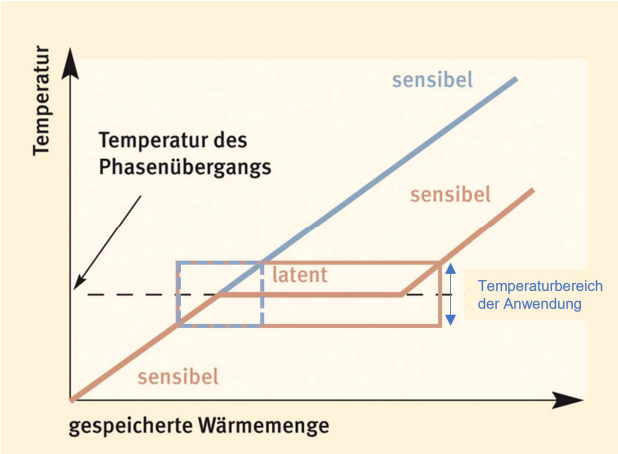

Figure 1 Temperature profile of a phase change material taking into account the melting process in comparison with a sensitive storage material such as water, wood or concrete

In technical applications, the operating temperature should often not fluctuate, or a certain temperature range must not be exceeded. With specifically used PCM, whose melting point is exactly in the temperature range of the application (e.g. 21°C for room air conditioning), considerably larger amounts of energy can be stored in the form of latent heat than in conventional storage materials (such as concrete, wood or water). In a fluctuation range of 3°C, which is common for room air conditioning, PCM can store around 35 times as much heat as concrete. However, PCM products available to date are essentially limited to use in transport boxes for temperature-sensitive medicines or food. They are offered in plastic containers in "cold pack form", which are adapted in shape and size to the shipping boxes.

MELT's product, on the other hand, is aimed at larger-scale applications. Salt hydrate-based PCMs with different melting temperatures are offered in customer-specific, modularly combinable plates - the MELT Plates. The materials are inexpensive and ecologically harmless (water hazard class 1 - like saline solution). The decisive advantage over products available on the market is the large-area and simple applicability, which is absolutely essential for the target customer group. This is achieved by a technological leap from (today's) three-dimensional to two-dimensional, endlessly extruded encapsulation forms in cross-section at MELT. This results in enormous flexibility over several orders of magnitude.

Extruded twin-wall sheets (multiwall sheets) made from recycled plastic serve as the basis for the MELT Plates. These are cut to size according to customer requirements, filled by robots and thermally sealed. The sealing process is difficult due to potential contamination by PCM and the low wall thickness of the sheets. New technologies, therefore, had to be developed that work reliably under these conditions.

4 MORE APPLICATIONS

In addition to the use in buildings for efficient load shifting in winter and passive overheating protection in summer, MELT Plates can be used profitably in many other applications. A small selection is explained in more detail in this chapter. Furthermore, they can be produced in any color, so there are no limits to design freedom. For the first time, PCM can, therefore, also be installed as visible elements (e.g. partition walls in open-plan offices or suspended ceilings). The load-bearing capacity of the panels is not impaired by their filling, so that they can also be used as a stabilizing component in a sandwich structure, for example.

4.1 Refrigerated vehicles

Refrigerated vehicles for transport of cooled nutrition products with electric drive can increase their range with MELT Plates and in some cases even completely dispense with a refrigeration unit.

For this purpose, the refrigerated vehicle is equipped with MELT plates containing cryohydrate. The cryohydrate (melting point minus 21 -°C) is loaded with cold at the factory at night and cools the refrigerated goods throughout the day.

4.2 Buffer tank of heat pumps

The thermal storage of heat generated by heat pumps in water storage tanks is very unfavourable because the heat pump has a poor efficiency if the sink temperature is too high. This means that all storage tanks based on the principle of sensitive heat can only store small amounts of heat per unit volume due to the small temperature difference. In the buffer tank of heat pumps, MELT Plates lead to less space requirements and larger storage capacities. In addition, lower storage temperatures reduce losses and increase the efficiency of heat pumps.

4.3 Industrial applications

Low-temperature waste heat can often not be reused well in industrial processes because the conventional, sensitive heat storage systems used to date require a temperature range that is not possible with low-temperature waste heat. This is more favourable with PCM storage systems, which can store and withdraw heat at a constant temperature. This means that industrial processes such as precipitation, humidification, drying, fermenters, food processing etc. can be supplied with heat at a constant temperature.

5 A PROTOTYPE FOR TEMPORARY BUILDINGS

As part of a research project by the Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB) to combat overheating problems in Bundeswehr containers, a 10ft container was to be equipped

with MELT Plates in order to achieve passive temperature buffering. The aim is to prevent overheating by flattening the temperature peaks to improve the containers used for storing temperature-sensitive materials or electronic components. Figure 2 shows the container before the installation of the panels.

Figure 2: Photographs of the original container – overvie w

5.1 Design and simulations

A 10ft container with the dimensions (length x width x height) 2990mmx2438mmx2438mm forms the basis of the investigations and is, therefore, the reference object.

MELT Plates are the basis for the PCM cladding. In order to protect the MELT Plates against mechanical loads from the outside and also to achieve a certain insulating effect, the plates were laminated with polyurethane (PU) foam on the outside. These, in turn, are additionally reinforced with 2 mm white GRP for increased mechanical stability and optimized optical properties (low emissivity). This results in a composite element with good optical and mechanical properties, which enables maximum retardation of thermal environmental influences in thin visible thicknesses.

The simulations were carried out using Designbuilder software, which is suitable for special building simulation applications. The phase change material and its effect could also be simulated here. Close consideration of the container geometry is necessary here, as real effects have a considerable influence on the behaviour of this type of temperature buffer. These include, in particular, thermal bridges on uncovered sections and the property of the phase change material to undercool. This results in the requirement to consider both, the temperature profile through the wall layer and the influences along the wall: A real 3D simulation is required.

The aim of the simulations was to determine the required layer thickness of the MELT Plates and the most appropriate melting point for this application. Two salt hydrate-based phase change materials with melting points of 21 °C and 25 °C are considered.

In order to be able to analyse the influence of the PCM in the wall layer, a reference simulation was created in the first step. All other simulated wall structures are measured against this. The reference container consists of a two-layer wall structure made of Corten steel and an internal wooden top layer. The floor structure is the same for all container versions tested and consists of a thicker wooden layer and also 7 mm Corten steel. The thickness of the steel sheets was calculated from the total mass of the container and its dimensions.

The encapsulation of the PCM contains supporting structures and also a certain amount of void volume. To avoid having to resolve this relatively complicated geometry numerically, mean values of the individual material values were used for the MELT Plates, which were weighted with the corresponding volume proportions. The heat of fusion (enthalpy of phase change) of the PCM used was assumed to be 101 kJ/kg (21 °C PCM) and 163 kJ/kg (25 °C PCM). Together with the high densities of 1580 kg/m³, the "MELT Plate 25" has a storage capacity of 2600 kJ/m² in the melting range (±2K around melting point) - as a practical comparison: a solid concrete wall with the same heat storage capacity in this small application temperature range would be 32 cm thick and would weigh 700 kg per square meter.

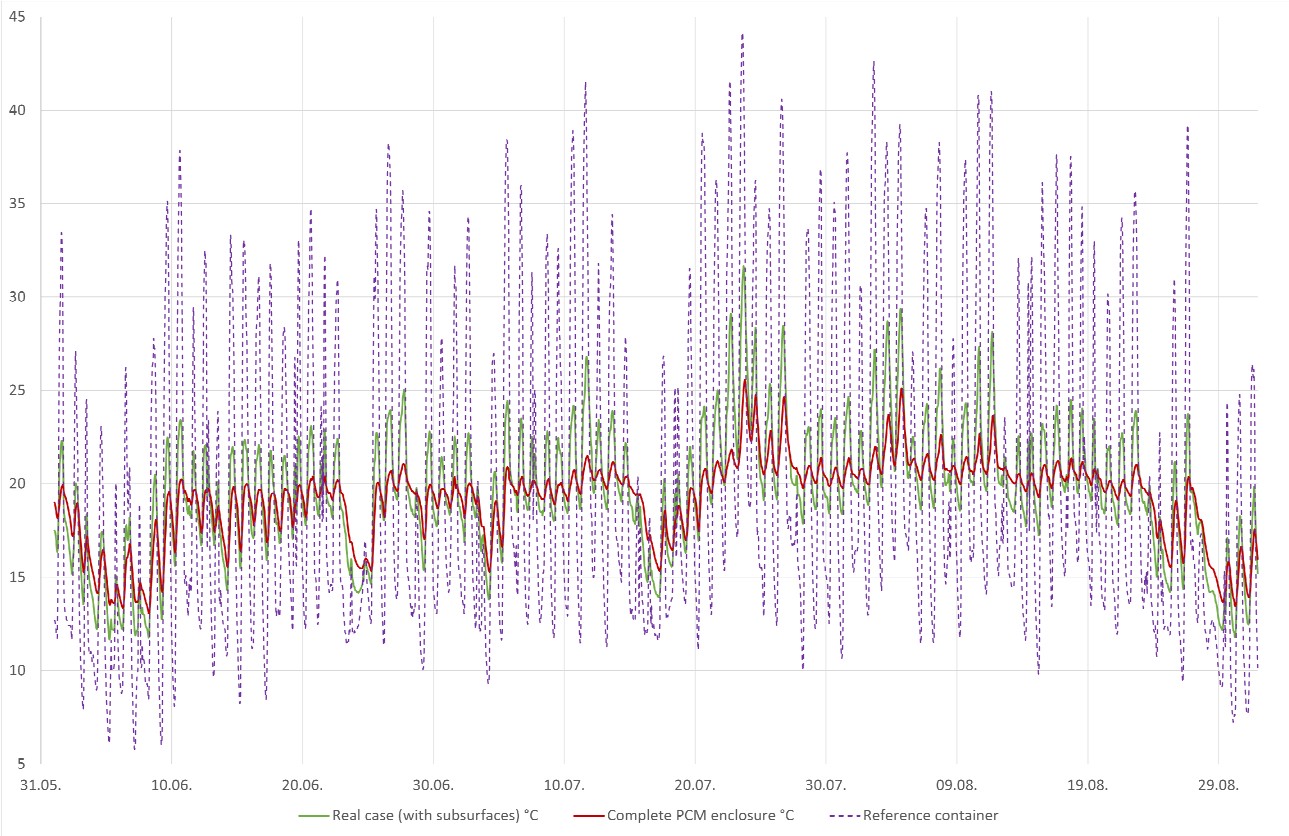

Figure 3: Simulated container temperatures for different cases (June - August in Munich, Germany) using 21 °C PCM

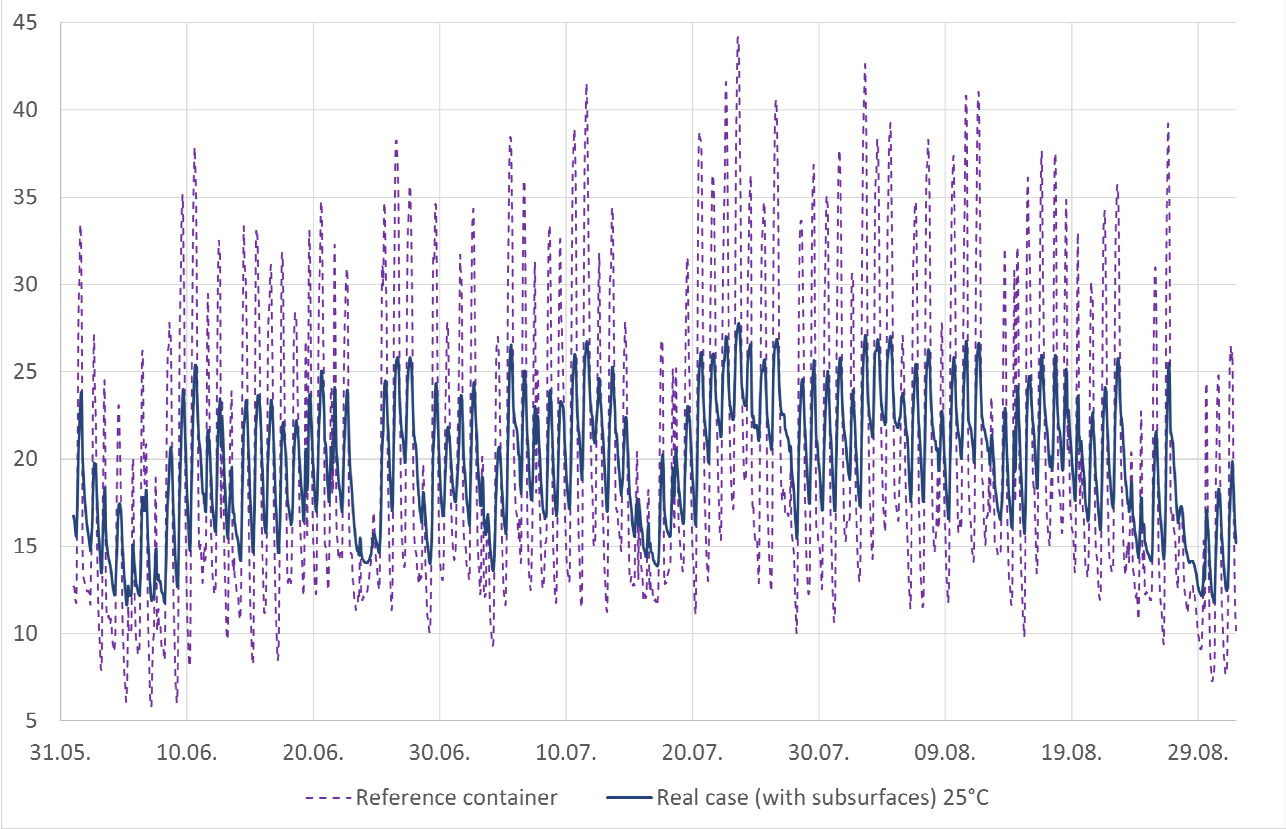

Figure 4: Simulated container temperatures for different cases (June - August in Munich, Germany) using 25 °C PCM

Figure 3 shows the simulation results of the temperature curves for three different container scenarios. The purple dashed line shows the internal temperature of the reference container without any use of PCM or other measures. The enormous temperature peaks caused by solar radiation clearly show the urgency of the measure. The green curve shows the expected curve for the implemented real case. Areas that could not be

fitted with MELT Plates due to structural restrictions are omitted here. As the test container was not built for this purpose, different structural conditions made complete enclosure impossible within this experiment. The red line shows the ideal application of MELT Plates with complete enclosure of the object. This temperature curve would probably have occurred under ideal structural conditions. MELT Plates 21, i.e. a phase change material with a melting temperature of 21 °C, were used for the simulation of both the red and green scenarios.

In comparison to that Figure 4 shows the simulation results of the same szenario using a PCM with melting temperature 25 °C instead of 21 °C, again compared with the reference container.

The simulation results show that the material with a melting point of 25 °C is better suited to preventing heat events of > 30 °C inside the container. As this was the primary requirement in the study presented in order to create optimum conditions for a storage scenario for temperature-sensitive objects, the 25 °C material was chosen for the implementation within the present project.

5.2 Application of the MELT Plates

The panels were ultimately designed with the following thickness throughout: 12 mm MELT panel 25 °C, 22.8 mm PU foam, 2 mm GRP panel. The wall connection cannot be carried out in reality as in the simulation (100% flush), which leads to poorer coupling.

This results in a total thickness of 36.8 mm with a tolerance of =+1 mm. The equipped container is shown inFigure 5. In the figure, the sub-surfaces, i.e. the areas that could not be equipped with the MELT Plate composite system, are clearly visible due to the beige colour.

Figure 5: Container equipped with phase change composite panels at the Erding site

5.3 Results and discussion

The period from 03.07.2023 to 27.09.2023 was evaluated. Figure 6 shows the comparison of the temperature curves of the different containers. In the first four days after the start of recording, the test container was not yet fitted with MELT Plates, so it still shows very similar behaviour to the reference container. The reference container is identical in construction to the test container. It has the colour RAL 6031-F9. After equipping the test container with MELT Plates, the temperature peaks were significantly reduced. As the heat protection concept with MELT Plates is not primarily based on reducing radiant emissions, but on latent heat storage, the energy collected during the day could be used to reduce the temperature drop at night. This not only reduced the temperature peaks, but also achieved a considerable reduction in day/night fluctuations.

This meant that the test container was in the desired temperature range of 20 - 25 °C for much longer than the comparison container and the critical limit temperature of 30 °C was reached or exceeded much less frequently. Nevertheless, it was found that the + 30 °C events were not completely avoided, as predicted in the simulation. The reason for this is initially assumed to be that the actual weather conditions during the test period deviated greatly from the simulated weather data. For example, the average temperature during the test period was 19.6 °C, while the simulations were based on an average temperature of 16.6 °C.

Looking at the experimental data set in general on a daily basis one can calculate the daily temperature spread and the “critical days”. Large spreads of the daily temperature indicate a higher cooling demand or, for cases without air conditioning installed, the deviation from a fixed storage temperature. High fluctuations

of temperature can lead to high humidity or water condensation on stored equipment. Figure 7 contains a box Plot of the spread as this shows the buffering effect of the MELT Plate very effectively. In the reference container only 28% of days had a spread lower than 7 K, while the container with MELT plate this increased to 90% of days. The days above the defined critical temperature range of 30°C were reduced from 45 days to 7 days, a reduction of 84%.

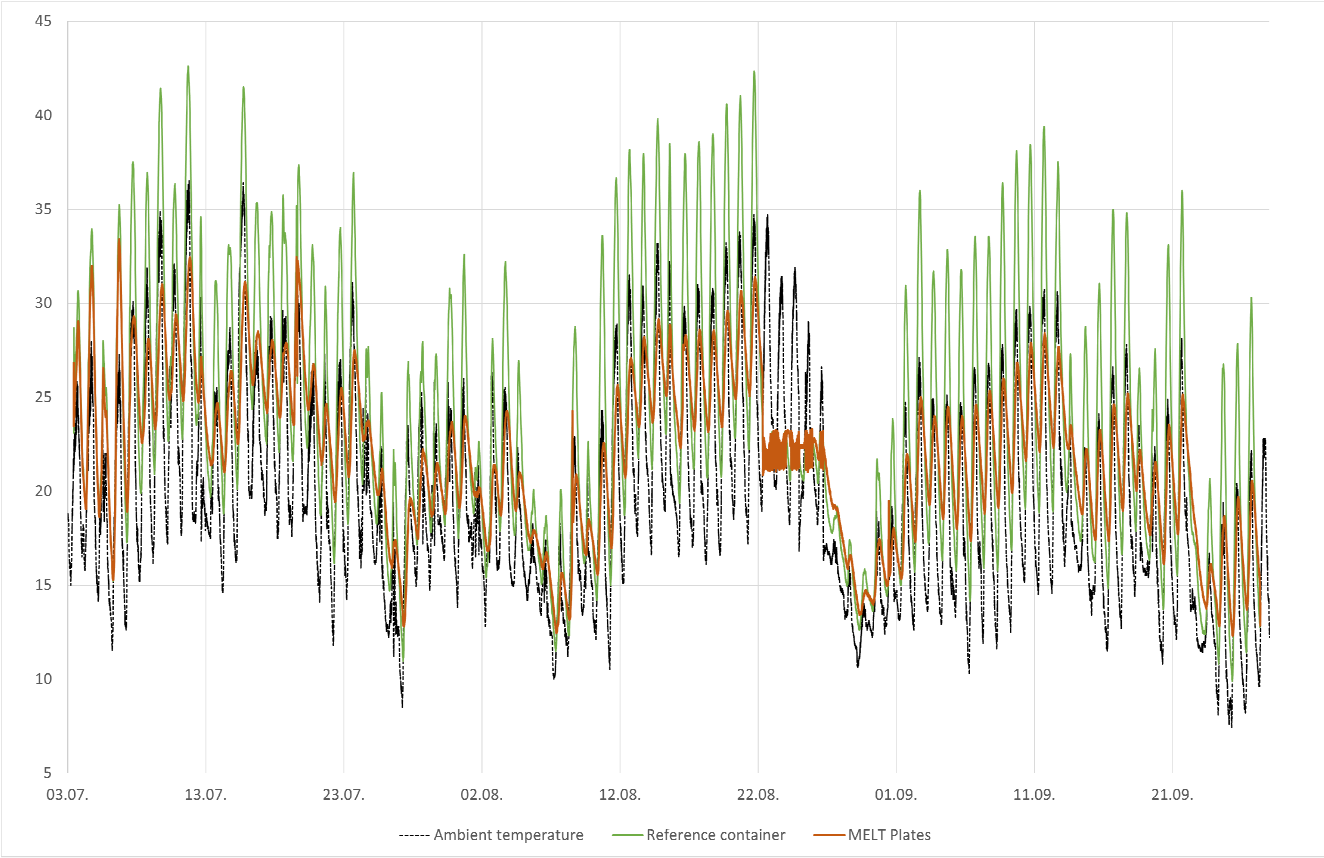

Figure 6: Temperature curves of the reference container compared to the container equipped with MELT Plates and the ambient temperature in the period 03.07.2023 - 27.09.2023. The special behavior from 22.08. to 30.08.2023 is due to the test operation of air conditioning systems, which will not be discussed in detail here.

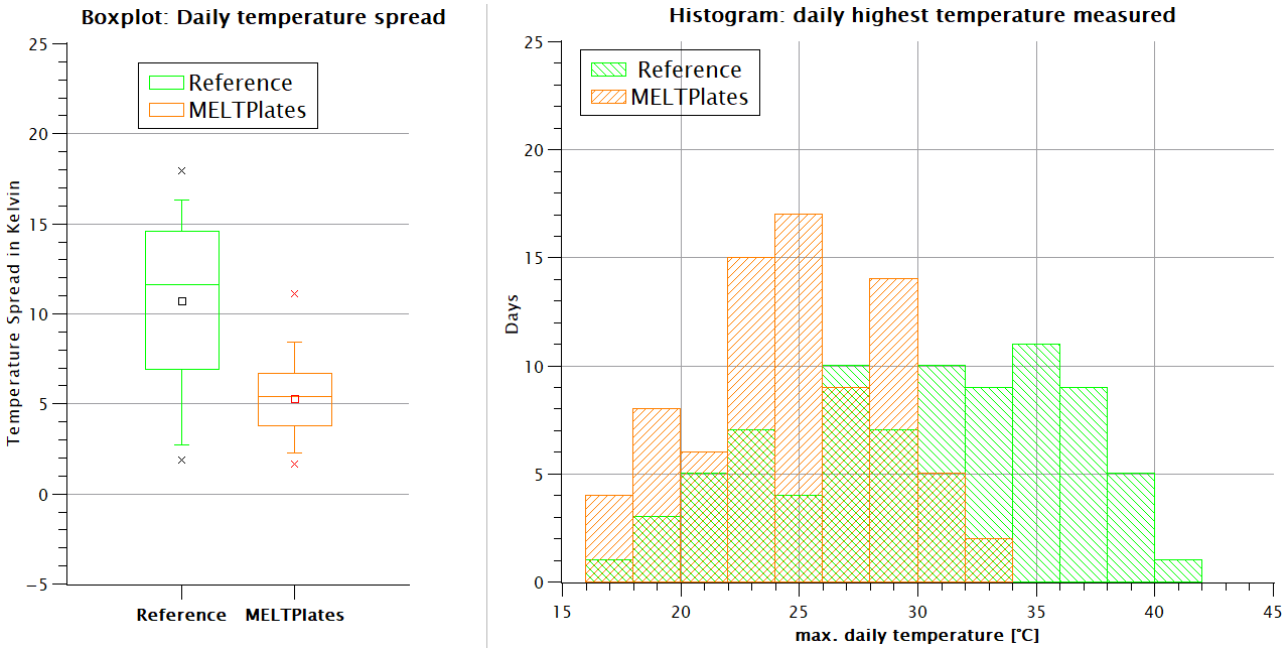

Figure 7: Experimental data on a daily basis: temperature spread and maximum values analysed

6 CONCLUSIONS

Thermal stabilization in buildings in general contributes to improving the feel-good climate that is increasingly required in buildings/homes (no more barrack climate) but also reduces the need for cooling. This leads, from a wellbeing perspective, to better recovery, better performance at work, and prevents extremely rapid temperature fluctuations if we consider specific climatic zones, or different climate conditions within buildings. However, phase change materials can also be used for passive temperature stabilization in special challenges such as the prevention of heat damage in storage scenarios, as in the study presented, provided they are available in a suitable presentation form, such as MELT Plates. From an ecological perspective, this reduces the building's CO2 footprint and the noise and waste heat pollution from air conditioning systems. Furthermore, by reducing the need for cooling, buildings equipped with the MELT Plates are more energy efficient leading to a long-term reduction in ongoing energy costs in summer and winter for residents or operators.

The potential of phase change materials for reducing the overheating of containers has been well illustrated by the previous considerations. However, there is potential for improvement above all in the installation of the elements on the container envelope. Due to the structural conditions on the container, a large part of the area could not be fitted with PCM panels (sub-surfaces, corner profiles, recess for air conditioning, power feed-through). Further investigations are planned to demonstrate the effect of a minimization of thermal bridges by either complete enclosure or combination with other technologies such as cooling coatings. Another approach would be to consider the performance of the panels in a different color, i.e. the influence of color on performance. Dark shades cannot be realized by cooling coatings, which is why PCM panels become interesting here for applications where a given cooler must be used.

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🏆 *reviewed paper*

Partizipation und Planung der aktiven Mobilität: Der Einsatz von Cape Revisos Methodenkoffer am Beispiel Herrenbergs

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1 ABSTRACT

Dieser Artikel stellt einen Auszug aus der Cape-Reviso-Toolbox vor, mit der das Ziel verfolgt wird, die spezifisc Wahrnehmung von Radfahrenden mithilfe digitaler Methoden besser erkennen und verstehen zu können. Die hier vorgestellten Module Nutzendenbefragung, Abstandsmessung, Emotionserkennung und KI-Kamerasystem wurden in Cape Reviso im Rahmen einessynchronen Testlaufs mit 16 Probandinnen und Probanden und fast 300 Datensätzen in der Stadt Herrenberg durchgeführt. Die Ergebnisse liefern hinsichtlich der Übertragbarkeit auf andere Projekte vielversprechende Ansätze hinsichtlich einer Skalierung des Erhebungsansatzes mit längerer Laufzeit, der eigenständigen Durchführung der Messungen durch die Testpersonen selbst, sowie die stärkere Integration in kommunale Planungsprozesse. Die Erkenntnisse des Projekts wurden mit Bürgerinnen, Bürgern, Entscheidungsträgerinnen und Entscheidungsträgern diskutiert und erweitern mit der Bereitstellung von quantifizierbaren Messdaten das lokale Wissen über Schwachstellen im kommunalen Radverkehrsnetz.

Keywords: Sensorik, Partizipation, aktive Mobilität, EmoCycling, Herrenberg

2 EINLEITUNG

Wo fühlen sich Radfahrende gestresst, welche Konflitkpotenziale entstehen zwischen verschiedenen Verkehrsteilnehmenden und inwiefern können diese Umstände in bürgerinnen- und bürgernahe Planungsprozesse berücksichtigt werden? Mit diesen Fragen beschäftigt sich das Projekt Cape Reviso (HLRS, 2024), das vom Bundesministerium für Digitales und Verkehr (BMDV, 2020) im Rahmen des Nationalen Radverkehrsplans 3.0 gefördert wird. In dessen Mittelpunkt stehen die Komponenten körpernahe Sensorik, Abstandsmessung und bildgebende Sensorik, die dazu beitragen, eine objektivere Sicht auf die subjektive Thematik des persönlichen Sicherheitsempfindens bzw. des erlebten Risikos zu schaffen. Der Artikel stellt drei Module aus der Cape Reviso Toolbox vor, die Sensortechnologien für Bürgerinnen, Bürger und Stadtverwaltungen enthält, die für den aktiven Einsatz in Beteiligungs- und Planungsprozessen konzipiert wurden. Als Fallbeispiel dient der Radverkehr in der Stadt Herrenberg.

3 STAND DER FORSCHUNG

Im Folgenden werden die wichtigsten Beispiele für das subjektive Sicherheitsempfinden im Zusammenhang mit dem Radfahren aufgeführt und die bereits erprobten Methoden und Technologien erläutert. Vertiefende Informationen hierzu finden sich z.B. in HAUG ET AL. (2023).

3.1 Die Rolle von Emotionen bei der Radverkehrsplanung

Internationale Studien zeigen, dass ein mangelndes Sicherheitsempfinden Menschen vom Radfahren abhalten kann. Diese Beobachtung gilt sowohl für Städte mit hohem, als auch für Städte mit niedrigem Radverkehrsanteil (WANG ET AL., 2014). Radverkehrsexpertinnen und Radverkehrsexperten wie GRAF (2016) sehen daher in der „Reduktion von Stress“ beim Radfahren einen Schlüsselfaktor für die Erhöhung des Radverkehrsanteils. Die Integration von „Stressmessungen“ als Indikator für ein mangelndes Sicherheitsempfinden beim Radfahren wurde bereits in mehreren Forschungsprojekten im internationalen Kontext beschrieben und eingesetzt (GÖTSCHI ET AL., 2018). Andere Studien fokussieren sich in diesem Kontext mehr auf den Ansatz der mobilen Beteiligung (LIßNER & FRANCKE, 2017). Das britische Near Miss Project liefert mit seinem Verständnis von „Beinahe-Unfällen“ oder „Nicht-Verletzungs-Unfällen“ ein fehlendes Bindeglied zwischen wahrgenommener Sicherheit und objektiver Sicherheit, das erklären könnte, warum Menschen vom Radfahren abgehalten werden. In ähnlicher Weise liefert dieser Ansatz durch die

Erstellung von Wegetagebüchern, in denen Informationen über Vorfälle mit Autofahrenden (z. B. zu dichtem Überholen) sowie über die Infrastruktur und das Verkehrsverhalten enthalten sind, wertvolle Informationen über Merkmale, die potenziell das Radfahren verhindern könnten. (ALDRED, 2016).

3.2 Der Einfluss persönlicher Merkmale auf das Mobilitätsverhalten

Sogenannte endogene Einflussfaktoren, die auf individuelle demografische, sozioökonomische und soziokulturelle Merkmale abzielen, sowie das soziale Umfeld der Individuen spielen eine entscheidende Rolle bei der Beeinflussung individueller Reaktionen auf Stressoren aus der gebauten Umwelt (WERMUTH 2005). Insbesondere das Alter - Kinder und ältere Menschen nehmen ihre Umgebung aufgrund unterschiedlicher Entwicklungsstadien oder altersbedingter Veränderungen unterschiedlich wahr - spielt dabei eine herausragende Rolle. Mobilitätsprofile, insbesondere bei Menschen mit Mobilitäts- oder Sehbehinderungen, sowie der Zweck der Fortbewegung und individuelle Gewohnheiten, wie z.B. die Bevorzugung des Autofahrens, beeinflussen die Anfälligkeit für Stressreaktionen (AUSSERER et al. 2013; SCHOON 2010). Auch das Geschlecht spielt eine Rolle, wobei Frauen tendenziell schneller auf Stressoren reagieren (KYRIAKOU & RESCH 2019). Psychologische Einflussfaktoren wie Persönlichkeitsmerkmale, Kontrollüberzeugung und Risikobereitschaft können die individuelle Stressreaktionen verstärken oder abschwächen (SCHANDRY 2016). Die Einbeziehung psychologischer Merkmale in wissenschaftliche Studien wird als wichtig erachtet, um Prozesse und Phänomene besser beschreiben und vorhersagen zu können (Persönlichkeit: RAMMSTEDT et al. 2012, Kontrollüberzeugung: KOVALEVA et al. 2012, Risikobereitschaft: BEIERLEIN et al. 2014). Die Persönlichkeit wird traditionell anhand der sogenannten Big Five bestimmt, die die Eigenschaften Extraversion, Neurotizismus, Offenheit, Gewissenhaftigkeit und Verträglichkeit umfassen. Die Kontrollüberzeugung beschreibt die Überzeugung einer Person, dass sie die Kontrolle über verschiedene Situationen hat und diese als Ergebnis ihrer Handlungen (internal) wahrnimmt oder sie dem Schicksal, dem Zufall oder mächtigen anderen (external) zuschreibt. Die Kontrollüberzeugung einer Person kann mit einer Charaktereigenschaft gleichgesetzt werden, da sie nachweislich das Verhalten erklärt und vorhersagt (KOVALEVA et al. 2012). Der Grad der Kontrollüberzeugung ist ein relevanter Faktor bei der Bewältigung von Stressreaktionen (BROSSCHOT et al. 1994). Die Risikobereitschaft gibt dabei an, inwieweit eine Person bereit ist, riskante Handlungsweisen zu wählen. Risikoverhalten wird empirisch mit dem Fahrverhalten in Verbindung gebracht und ist daher von Bedeutung.

3.3 Digitale Tools und Sensoren als Mittel informationeller Gleichstellung

Ohne die Herstellung einer „informationellen Waffengleichheit“ ist jede Form der Partizipation bedeutungslos (STREICH 2014, 137). Ein guter Partizipationsprozess sollte sich deshalb daran messen lassen, wie viele Informationen zur Verfügung gestellt werden. Laut STREICH (2014) erfordert echte Partizipation nicht nur die Verfügbarkeit von Daten, sondern auch technisch-organisatorische Maßnahmen. Inspiriert von der PlaceMatters-Initiative plädiert er für „offene Werkzeuge“, insbesondere „Open-Source-Planungstools“, die mit offengelegtem Quellcode für alle zugänglich sind (STREICH 2014, 137 & 148). Daher sind fast alle Methoden und Technologien, die in diesem Ansatz verwendet werden, offen, wie unten beschrieben. Für die Erkennung von Beinaheunfällen, subjektiver Sicherheit und „Stress“ gibt es eine Reihe von unterschiedlichen Sensoren: Stationäre Sensoren zum „Dynamic Scene Understanding“ (BUXTON 2003), die automatisierte Detektion und Klassifizierung von Fußgängern (ROMERO-CANO et al. 2016), mobile Handsensoren wie GPS-Empfänger oder Mikrofone zur Erfassung von Geräuschen (MAISONNEUVE et al. 2008), Lichtintensität und Farbe (GUTIERREZ-MARTINEZ et al. 2017), Schadstoffkonzentrationen über USB-Schnittstelle (SCHÄFER et al. 2017) oder auch biostatistische Sensoren (KANJO et al. 2015).

4 CAPE-REVISO-TOOLBOX

In Cape Reviso werden verschiedene Methoden zum Einsatz gebracht, die entweder aufeinander aufbauen oder unabhängig voneinander Messergebnisse liefern. Sensorgestütze Stressmessungen, standardisierte Fragebögen, Abstandsmessungen und maschinelles Lernen in Form einer Langzeiterfassung des Verkehrsgeschehens dienen in diesem Zusammenhang der Analyse und Reduzierung von Konflikten zwischen Radfahrenden und anderen Verkehrsteilnehmenden. Prinzipiell können die einzelnen Elemente auch für sich alleine genutzt werden, ihre Stärke liegt jedoch in der Verknüpfung untereinander. Die einzelnen Module werden im Folgenden erläutert.

4.1 Sensorgestützte Stressmessungen und standardisierte Fragebögen

Zur Durchführung der „Stressmessungen“ in diesem Projekt werden Sensorarmbänder (Empatica e4) verwendet, um die Vitaldaten (Hautleitfähigkeit und Hauttemperatur) der Testperson während der Fahrradnutzung zu messen. Die Vitaldaten werden mit den korrespondierenden GPS-Daten über ein Smartphone synchronisiert. Eine Stressreaktion wird in der Auswertung erkannt, wenn die Hautleitfähigkeit steigt und die Hauttemperatur sinkt (KYRIAKOU ET AL., 2019). Durch die Kombination mit einer Mixed-Methods-Befragung der Teilnehmenden können die identifizierten Stresspunkte im Anschluss dann genauer hinsichtlich verschiedener Merkmale betrachtet werden. Diese subjektive Belastungseinschätzung kann wiederum durch Informationen über das Mobilitätsprofil, soziodemografische sowie sozialpsychologische Annahmen weiter spezifiziert werden. Diese Daten werden vor den Sensormessungen mittels standardisierter Fragebögen erhoben und in die Auswertung einbezogen. Mit dieser Methodik zielt der vorgestellte Ansatz darauf ab, besonders gefährdete Gruppen in Bezug auf Stress zu identifizieren.

4.2 Netzwerkanalyse mit dem OpenBikeSensor

Der sogenannte OpenBikeSensor (OBS) wurde als offene Sensorplattform konzipiert (GITHUB, 2021). Ultraschallsensoren messen kontinuierlich den physischen Abstand zu anderen Verkehrsteilnehmenden und speichern diesen georeferenziert. Durch die Aggregation aller Datensätze ist es möglich, Bereiche zu identifizieren, in denen Überholvorgänge in einem Abstand von weniger als 150 cm gehäuft auftreten. In Kombination mit Daten aus der Verkehrsüberwachung etc. ergeben sich so erste Verdachtspunkte für potenzielle Hotspots von Beinahe-Unfällen und anderen Konfliktbereichen.

4.3 Machine Learning/Trainingsdatengenerierung/Kamerasystem

Das System, das an (Beinahe-)Unfallschwerpunkten eingesetzt wird, nutzt stationäre Kamerasysteme für die Langzeitaufzeichnung von Videodaten zur Untersuchung von Konflikten, Gefahrensituationen und Unfällen. Das System besteht aus einer Kamera, die mit einer eingebetteten Computerplatine mit einem leistungsstarken Grafikprozessor (NVidia Jetson AGX Xavier, 32 TOPS) verbunden ist, und ermöglicht Edge Computing für die Verarbeitung von Bilddaten vor Ort unter Verwendung von Algorithmen für maschinelles Lernen. Dieser Ansatz stellt sicher, dass die Bilddaten im temporären Speicher des Systems verbleiben und in anonymisierte Verkehrsmetadaten umgewandelt werden, um die Einhaltung des Datenschutzes zu gewährleisten. Das modulare Softwaredesign, welches die Erkennung, Verfolgung und Trajektorienanalyse umfasst, beinhaltet klar definierte Schnittstellen für die schnelle Integration neu entwickelter Algorithmen von Drittanbietern.

Für die Bilderkennung verwendet das System das Convolutional Neural Network YOLO (REDMON & FARHADI, 2016) mit der Deep Neural Network Library tkDNN (VERUCCHI ET AL., 2020), dass bei FullHD-Videos mit etwa 40 Bildern pro Sekunde arbeitet, wobei die Erkennungsergebnisse lokal gespeichert oder im JSON-Format gestreamt werden. Es wurde mit dem COCO-Erkennungsdatensatz (LIN ET AL., 2015) und der ImageNet-Klassifikationsdatenbank trainiert. Die Anpassungen für den europäischen/deutschen Mikromobilitäts-Mix umfassen ein Webportal (https://capereviso-portal.hlrs.de/), das das Image Labeling Tool (KIM, 2019) für Crowdsourcing von zusätzlichen Klassifikationsdaten nutzt. Das Portal erleichterte die Interaktion mit Freiwilligen, was zu Trainingsdaten für die Klassifizierung verschiedener Verkehrsteilnehmer führte, darunter Fahrräder, Zufußgehender, Motorroller, Rollstühle und Personen mit Kinderwagen.

Im Rahmen des Projekts wurden drei Tracking-Algorithmen getestet und teilweise implementiert. Das Poisson-Multi-Bernoulli-Gemisch (BOHNSACK, 2019) wurde für das Live-Tracking erweitert, und es wurde ein Multikamerasystem mit Sensorfusion erforscht (VALDER, 2021). SORT (BEWLEY ET AL., 2016) zeigte vielversprechende Ergebnisse in Ein-Kamera-Systemen, und es wird daran gearbeitet, DeepSORT (WOJKE ET AL., 2017) auf Mehr-Kamera-Systeme zu erweitern. Die Trajektorienanalyse reicht von der einfachen Zählung von Verkehrsteilnehmenden bis hin zu tiefgreifenden Untersuchungen komplexer Interaktionen. Kritikalitätsmetriken (WESTHOFEN ET AL., 2023), die für gefährdete Verkehrsteilnehmende angepasst wurden, bieten Einblicke in Konfliktmechanismen und unterscheiden einzelne extreme Ereignisse von wiederkehrenden Ereignissen. Neben Geschwindigkeits- und Beschleunigungsmetriken die Trajektorienanalyse TTCE (time to closest encounter, engl.: Zeit bis zur nächsten Begegnung) und DCE (distance of closest encounter, egl.: Entfernung bis zu nächsten Begegnung)

umfassen, mit möglichen Erweiterungen zur Identifizierung von Infrastrukturen, die kritische Begegnungen fördern.

5 ERGEBNISSE DER FALLSTUDIE HERRENBERG

Die Partnergemeinde Herrenberg dient als Beispiel, um die Nutzung der Toolbox von Cape Reviso zu veranschaulichen. Herrenberg liegt im Südwesten Deutschlands, 40 km südwestlich von Stuttgart. Mit 33.000 Einwohnerinnen und Einwohnern kann sie als mittelgroße Stadt eingeordnet werden. Im Jahr 2016 ergab der Modal Split einen Radverkehrsanteil von 11 % und einen Fußverkehrsanteil von 19 % (MEIGL ET AL., 2019). Im Rahmen von Cape Reviso wurden im Herbst 2022 verschiedene Erhebungen durchgeführt. Dazu gehören Stress- und Entfernungsmessungen über zwei Wochen mit 16 Teilnehmenden sowie der Einsatz des Kamerasystems. Trotz der Tatsache, dass 16 Teilnehmende für die Bevölkerung Herrenbergs nicht als repräsentativ betrachtet werden können, ist dennoch die besondere Bedeutung des Testlaufs hervorzuheben. Denn im Rahmen dieses Testlauf wurdeerstmals die synchrone Nutzung der beschriebenen Technologien in Verbindung mit den standardisierten Fragebögen erprobt. Dabei wurde die Skalierbarkeit von der reinen Einzelauswertung (wie in den Urban Emotion Cycling Experimenten ZEILE et al. 2016) bis zur unbeaufsichtigten täglichen Nutzung getestet.

5.1 Beschriebung der Stichprobe mit standardisierten Fragebögen

Die standardisierten Fragebögen gewähren Einblicke in das Radfahrverhalten, die Persönlichkeitsmerkmale und die Einstellungen der Teilnehmenden, die ihre Präferenzen und ihr Verhalten in Bezug auf das Radfahren beeinflussen können (vgl. Tabelle 1.). Die Mehrheit (69 %) der Teilnehmenden ist über 40 Jahre alt, mit einem leichten Überschuss an Menschen, die sich als Frauen identifizieren (59%). Ein erheblicher Teil (81%) hat einen hohen Bildungsgrad. Die Teilnehmenden werden in Radfahrertypen eingeteilt (GELLER, 2009), wobei die Mehrheit „Alltagsradfahrende“ (56%) und „interessierte Radfahrende“ (44%) sind. Daher sind in der Studie keine extremen Positionen zum Radfahrverhalten vertreten. Die meisten Teilnehmenden (81%) fahren mit Muskelkraft, 19% nutzen E-Bikes. Häufige Fahrradtypen sind Trekkingräder (50%) und Cityräder (31%). Herrenberg wird laut Fahrradklimatest des ADFC (Note= 3,9, N= 154) beim Zufußgehen als durchschnittlich (Note 3,4) und beim Radfahren als schlecht (Note 4,1) bewertet. „Konflikte mit Zufußgehenden“ (Note: 4,1) sind ein besonderes Anliegen der Herrenberger Radfahrenden, der Faktor wird um 0,5 Notenpunkte schlechter bewertet wird als im Durchschnitt vergleichbarere Städte (ADFC 2022).

Variable	**$N_{Teilnehmende}$=16 (in %)**
Alter (>40)	69
Gender (female)	56
Bildung, hoch	81
Radfahrtypen (Geller 2009)	
Keine Chnace, egal wie	0
Interessierte Radfahrende	44
Alltagsradsfahrende	56
Furchtlose Radfahrende	0
Fahrradantrieb	
Konventionell	81
Elektrisch	19
Fahrradtyp (am häufigsten genutzt)	
Trekking Fahrrad	50
City Fahrrad	31
Bewertung der Verkehrssituation in Herrenberg (Schulnoten)	
Radfahren	Ø 4.1
Zufußgehen	Ø 3.4
Big-Five-Persönlichkeitsmerkmale	
Extraversion (überdurchschnittlich)	57
Neurotizismus (überdurchschnittlich)	71
Offenheit (überdurchschnittlich)	64
Gewissenhaftigkeit (unterdurchschnittlich)	79
Verträglichkeit (unterdurchschnittlich)	33
Kontrollüberzeugung	
Internal (unterdurchschnittlich)	73
External (unterdurchschnittlich)	80
Risikobereitschaft (hoch)	73

Tabelle 1: Beschreibung der Stichprobe, eigene Berechnungen

Die Teilnehmenden weisen ausgeprägte Persönlichkeitsmerkmale auf (RAMMSTEDT et al. 2012), mit einem höheren Grad an Extraversion, Neurotizismus und Offenheit im Vergleich zum deutschen

Durchschnitt. Sie sind weniger gewissenhaft und sozial verträglich. Die Ausprägung der Kontrollüberzeugung zeigt in Herrenberg eine Präferenz für internale Kontrolle. Im Durchschnitt besitzen die Teilnehmenden eine hohe Risikoaffinität (73 %) (BEIERLEIN et al. 2015).

5.2 Sensorgestütze Stressmessungen

Bei der Messung der Vitalwerte (Hautleitfähigkeit, Hauttemperatur) von 16 Testpersonen zur Stresserkennung wurden 283 Datensätzen erfasst. Die reine Fahrzeit der Probandinnen und Probanden betrug 58,46 Stunden, was 210467 Messpunkten entspricht. Dabei wurden 5422 Stressmomente (MOS) festgestellt. Abbildung 2 zeigt die gesamte Messkampagne über das Stadtgebiet von Herrenberg (links) sowie einen Schwerpunktbereich um den Reinhold-Schickplatz und die angrenzende Ringstraße (rechts). Hier wurde eine hohe Anzahl von MOS festgestellt, was mit dem „lokalen Wissen“ über die hohe Verkehrsproblematik an diesem Ort einhergeht.

Abbildung 2: Alle Messpunkte und MOS-Detektion in Herrenberg (links) und mit Fokuspunkt auf dem Reinhold-Schickplatz (rechts)

Anhand von Fragebögen und anonymisierten Stressdaten wurden erste Auswertungen auf Basis von Persönlichkeitsmerkmalen durchgeführt. Zu den wichtigsten Untersuchungen gehören in diesem Zusammenhang geschlechtsspezifische Unterschiede und die Unterscheidung in Radfahrtypen (Abb. 3).

Abbildung 3: Unterschiedliche Stress-Hotspots der Radfahrtypen „Interessierter Radfahrende“ (links) und „Alltagsradler“ (rechts)

5.3 Netzwerkanalyse mit dem OpenBikeSensor

Bis November 2022 wurden im Untersuchungsgebiet über 210.000 Punkte erfasst. Von den 402 erfassten Überholvorgängen waren 179 Nahüberholungen unter 150 cm. Zu den Hotspots gehören der Reinhold-Schickplatz, die Horber Straße und die Hindenburgstraße. Aufschlüsselung der Nahüberholungen: 25 im Bereich 0-50 cm, 53 im Bereich 50-100 cm und 101 im Bereich 100-150 cm. Weitere Punkte (64 in 150-200 cm und 41 >200 cm) liegen außerhalb der gesetzlichen Mindestabstände, werden aber dennoch als „Nahmanöver“ wahrgenommen. Insbesondere auf Straßen mit erlaubter Geschwindigkeit von mehr als 50 km/h erfahren Radfahrende starke seitliche Kräfte, die ihr subjektives Sicherheitsempfinden beeinträchtigen können (GROMKE & RUCK, 2021).

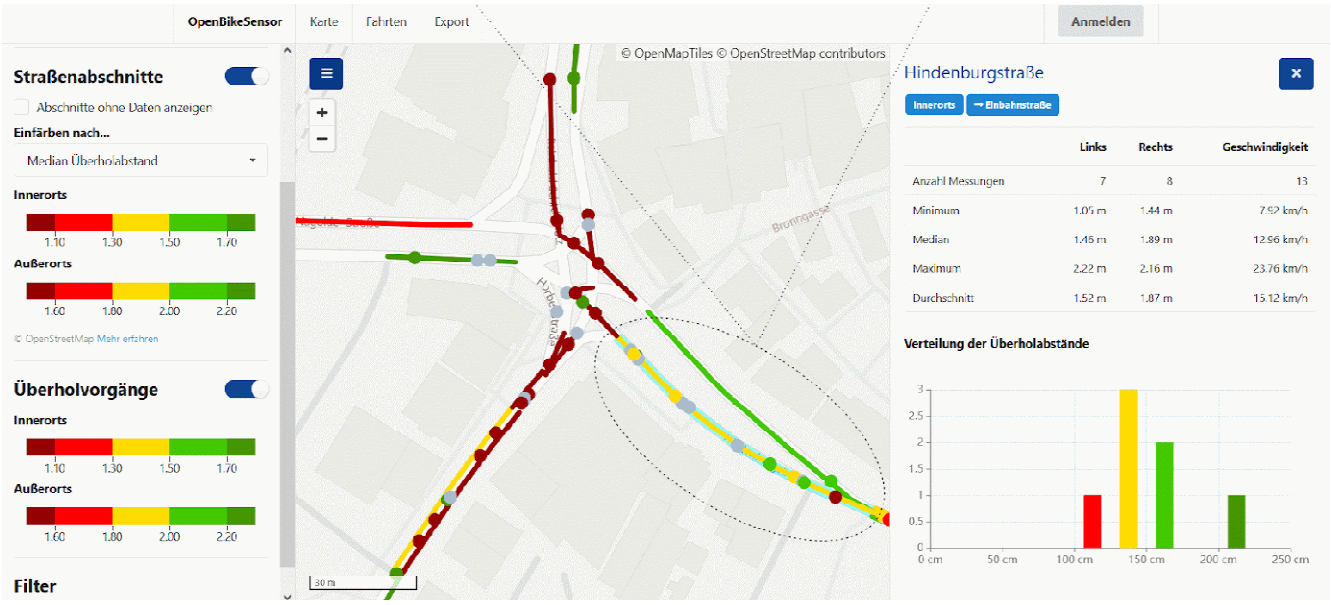

Abbildung 1: Aus dem OBS-Portal generierte Informationen, zugeschnitten auf Herrenberg (https://openbikesensor.hlrs.de/map#17.66/48.59486925734776/8.867378921008): Focus Spot mit statistischen Informationen zu einem Straßenabschnitt.

5.4 Langzeiterfassung des Verlehrsgeschehens mittels Kamerasystem

Zwischen 2022 und 2023 zeichneten die Herrenberger Verkehrsdetektionssysteme an über 1600 Tagen an fünf Systemen und neun Standorten auf. Aufgrund von Einschränkungen im Tracking-Algorithmus wurden reine Erfassungen auf Einzelbildern gespeichert und später mit angepassten Algorithmen analysiert. Die Auswahl der zu untersuchenden Bereiche erfolgte auf der Grundlage der Daten mobiler Sensoren und der Erfahrungen der Kommunen. In diesem Zusammenhang liefert die Analyse der räumlichen Dichte Einblicke in die Verkehrswege und zeigt die Hauptrouten der verschiedenen Verkehrsteilnehmer auf. Abbildung 4 veranschaulicht die Ergebnisse des Kameraerfassungssystems an der Volkshochschule Herrenberg. Außerdem können einzelne Trajektorien von Interesse zusammen mit den anderen Verkehrsteilnehmenden, die zu einem bestimmten Zeitpunkt anwesend sind, angezeigt werden. Allerdings werden detailierte Abläufe eines Konflikts immer noch nicht zuverlässig erkannt. Zu nahes Überholen z.B. oder das Schneiden der Fahrtlinie können nicht ausgemacht werden. Verfolgungsverluste und Rauschen in der exakten räumlichen Ausdehnung führen zu Unsicherheiten, die eine Weiterentwicklung der Erkennungsstabilisierung und Filterung erfordern. Die detaillierteste Analyse wurde vor der Volkshochschule in Herrenberg durchgeführt, wo die allgemeine Verkehrssituation deutlich von motorisierten Fahrzeugen dominiert wird.

An dieser Stelle müssen sich Radfahrende, die aus Richtung Osten kommen, entscheiden, ob sie sich mit dem motorisierten Verkehr, der von einer Landstraße in Herrenberg einfährt, mischen oder gesetzeswidrig den Gehweg benutzen wollen. Aus zweiterer Entscheidung können jedoch Konfikte mit dem Fußverkehr resultieren. Ob der Gehweg rechtlich für Radfahrende geöffnet werden kann, ist eine laufende Diskussion in Herrenberg. Die bisherigen Annahmen über die derzeitige Wegenutzung können durch die Analysen des Kamerasystems bestätigt werden.

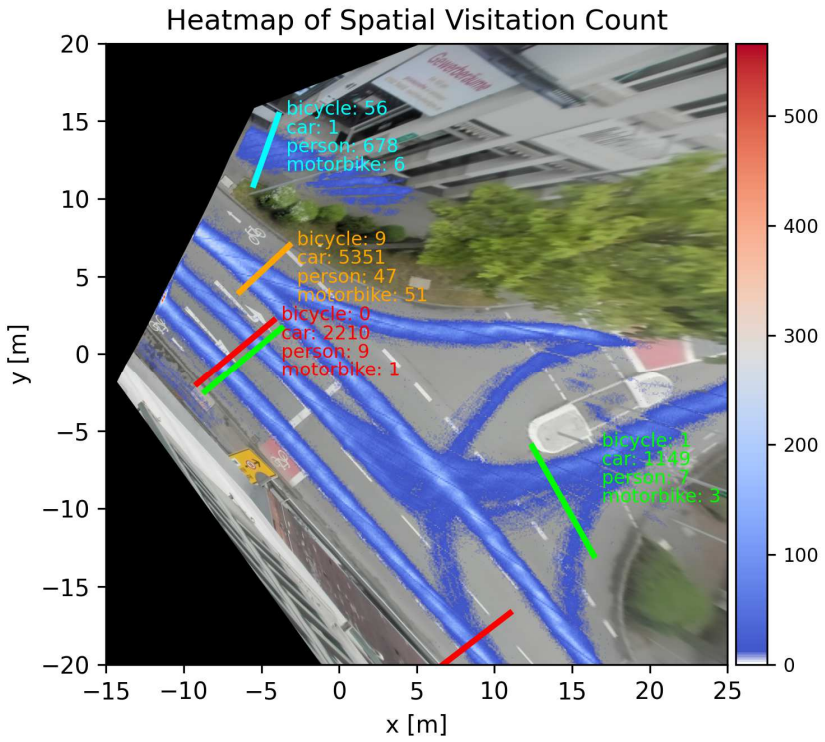

Abbildung 4: Kameraaufzeichnungen an der Volkshochschule Herrenberg. Räumliche Verteilung der Besuchszahlen der Verkehrsteilnehmenden am Referenzpunkt auf einem Raster mit 0,1 m Auflösung zusammen mit den Zählungen von ein- (cyan und orange) und mehrspurigen Kreuzungen (rot und grün). Kumulierte Daten vom 1. Mai 2023

5.5 Verknüpfung der Tools

Perspektivisch birgt die Verknüpfung aller Ansätze ein großes Potenzial: Das gesamte Straßennetz wird auf Stresssituationen der Radfahrenden gescannt und gleichzeitig kritische Überholabstände protokolliert. Durch diesen Gefährdungsnachweis können wertvolle Daten hinsichtlich einer möglichen Neudimensionierung der Radwege gewonnen werden. An den identifizierten Hotspots wurden mit dem Kamerasystem Schwerpunktanalysen durchgeführt und die Ergebnisse der Stressmessungen können Aufschluss darüber geben, welche Stellen von „Umsteigenden“ – also der Gruppe der Interessierten Radfahrenden - besonders gemieden werden. In diesem Experiment wurden die Kamerastandorte an den identifizierten Hotspots eingerichtet. Insbesondere an einem Fokusbereich, der Volkshochschule, konnten wir kontextuelle Vorteile für die Kameraaufzeichnungen identifizieren. Bei der Analyse der Verkehrsströme und der tatsächlich gefahrenen Strecken konnten wir feststellen, dass Radfahrende den Gehweg der Straße vorziehen. Die eigentliche Radverkehrsinfrastruktur wurde gemieden und es gab weniger MOS als erwartet und keine Unfälle in der Unfallstatistik. Die Toolbox kann genutzt werden, um z.B. funktionale von dysfunktionalen Verkehrssituationen zu unterscheiden, und kann Informationen für die Stadtplanung liefern, um Maßnahmen zu priorisieren. Weiterhin konnte keine eindeutige Korrelation zwischen einem geringen Überholabstand und den einzelnen Stressauslösern festgestellt werden: An einigen Stellen ist dies der Fall, an anderen Stellen mit sehr geringen Abständen wurden jedoch keine Stressmomente registriert (siehe Abb. 5).

Dieses Phänomen deckt sich auch mit den Ergebnissen von HAUENSTEIN et al. (2023): Ein erhöhter Belastungszusammenhang bei geringeren Überholabständen unter 1,6 m ist mit dem Pearson's Chi-Quadrat-Test statistisch nachweisbar, aber nicht für jeden Belastungsauslöser „sichtbar“. Die Überlagerung beider Messungen unterstützt somit systemisch die gesetzliche Forderung nach einem Überholabstand von 1,5 m innerorts, aber als kombinierte Anwendung im Planungskontext des Radverkehrs liefern beide Messreihen zusammen nicht die erforderlichen Hinweise. Interessant wäre in diesem Zusammenhang aber auch, ob es eine statistische Korrelation zwischen Stressauslösern, Abstand und den oben genannten Persönlichkeitsmerkmalen gibt.

Abbildung 5: Korrelationen zwischen Überholabstand und MOS am Fokuspunkt Reinhold-Schickplatz, eigene Darstellung

6 CONCLUSIO

Im Rahmen des Projekts Cape Reviso wurde eine Toolbox entwickelt, die biostatistische Sensoren, Distanzmesser und ein Kamerasystem für die Beteiligung von Bürgerinnen, Bürgern und Stadtverwaltung an Planungsprozessen umfasst. Ausgehend von der Intention, Konflikte zwischen Radfahrenden und Zufußgehenden messen zu können, sind die hier vorgestellten Ergebnisse in Kombination mit den Untersuchungen zum Fußverkehr am Stuttgarter Marienplatz (SCHMIDT-HAMBURGER et al. 2023) ein wichtiger Baustein zum Verständnis vom Stressempfinden und Konflikten zwischen Radfahrenden und Zufußgehenden.

Alles in allem zeigt das Beispiel Herrenberg, wie eine bürgerinnen- und bürgernahe Planung zu einem sichereren städtischen Umfeld beitragen kann. Der methodische Ansatz ist offen gestaltet und ermutigt Planende in den Gemeinden zur Nachahmung und Umsetzung. Während die multisensorische Toolbox einen ganzheitlichen Analyseansatz mit Stärken wie Kosteneffizienz und Anpassungsfähigkeit demonstriert, gibt es jedoch auch Einschränkungen. Hierbei sind zum Beispieldie kleine und heterogene Stichprobe bei den Stress- und Abstandsmessungen, Herausforderungen beim Ableiten präziser Schlussfolgerungen aus Kameraaufzeichnungen, sowieaktuelle Beschränkungen bei digitalen Zwillingsmessungen zu nennen. Ferner wurde die Durchführung des Projekts auch durch die Beschränkungen der COVID-19 Pandemie in den Jahren 2020-2023 eingeschränkt. Trotz dieser Einschränkungen ist die Toolbox vielversprechend für die weitere Entwicklung und den Einsatz in der Stadtplanung, insbesondere mit ihrem Schwerpunkt auf Partizipation von Bürgerinnen und Bürgern und multisensorischer Datenintegration.

7 DANKSAGUNG

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Policy and Legislative Enabling Environment for Implementing Digital Technologies in the Local Government Sector: a Case Study of South Africa

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1 ABSTRACT

The Fourth Industrial Revolution has necessitated all organizations, private and public alike, to review their systems, processes, and frameworks to enable them to be agile, efficient, effective, etc in executing their core service delivery mandates. A key component of enablers for digital transfromation is policy and legislation. Focussing on the municipal sector, this paper is an attempt to provide an overview of the policies, regulations, and legislation affecting municipalities in South Africa and to analyze the extent to which these policies and legislation enable or inhibit the rollout of digital technologies. The paper isbased on a desktop literature review and a review of policies and laws having a direct bearing on the operations of municipalities in South Africa. The preliminary results lead the authors to conclude that South African municipalities do not have a deficit of policy and legislative frameworks to enable them to roll out digital technologies. So, what is needed more is the administrative and political will to execute. However, the authors assert that going forward, there are areas that need further attention. These include resolving the funding modalities, and developing supportive framework/s to guide municipalities so that as they roll out digital technologies, they don't risk sustainability imperatives.

Keywords: smart city, South African municipalities, fourth industrial revolution, policies, legislation

2 INTRODUCTION

The local government sector in South Africa is highly regulated, and some policies guide managers on how to run the affairs of a municipality. A key component of enablers is policy and legislation. In the context of the Fourth Industrial Revolution, it is necessary to understand the extent to which the policies, regulations, and legislation affecting municipalities in South Africa enable or inhibit the rollout of digital technologies. This is the quest of this paper. A systematic review of policies and laws having a bearing on the operations of municipalities in South Africa was done to achieve this purpose.

3 POLICY, REGULATION, AND LEGISLATION IMPACTING THE USE OF DIGITAL TECHNOLOGIES BY MUNICIPALITIES IN SOUTH AFRICA

The following section discusses policy and legislative issues affecting the deployment of digital technologies in South African municipalities.

3.1 Some critical policy issues related to digital technologies and municipalities in South Africa

Here are some of the critical policy issues related to the use of digital technologies by municipalities in South Africa.

3.1.1 Access to the Internet

One of the critical policy issues in South Africa as far as digital technologies are concerned is that approximately 68% of the South African population nationally, or 41 million, have internet access (Statista, 2022). Through the S.A. Connect Initiative, the South African Government has set an ambitious target of achieving 100% broadband access to everyone by 2030. In this regard, cities can play a huge role in the fulfillment of this goal (Hypertext, 2018). In addition, President Cyril Ramaphosa has pronounced a vision of a Smart City in South Africa through his 2022 State of the Nation Address (SONA). The Smart City Vision aims to build post-apartheid cities that are based on principles of urban sustainability (Mzekandaba, 2021).

3.1.2 ICT connectivity

The Table below shows the percentage of people per 100,000 who have access to ICT connection in the South African cities.

Name of city	Fixed landline telephone	Mobile telephone	Internet connection
City of Cape Town	18.5%	98.2%	78.7%
Johannesburg	9.1%	99.6%	76.8%
Tshwane	8.2%	99.6%	75.2%
eThekwini	12.5%	99.2%	75.0%
Nelson Mandela Bay (NMB)	8.3%	94.7%	84.2%
Ekurhuleni	10.0%	99.3%	83.2%
Mangaung	12.4%	95.9%	70.8%
Buffalo city	6.7%	94.9%	69.4%
TOTAL/AVERAGE	10.7%	97.6%	76.6%

Table 1: Percentage of people who have access to ICT connection in RSA cities. Source: Authors (2023), based on SACN, 2021 (+own calculations).

In terms of fixed landline access, the City of Cape Town is leading at 18%, followed by eThekwini (12.5%) and Mangaung (12.4%). The lowest is Buffalo City at 6.7%. In terms of access to mobile telephones, all South African cities are above 95%. However, in terms of internet connectivity, the highest is Nelson Mandela Bay (84.2%) followed by Ekurhuleni (83.2%). The City of Cape Town follows at 78.7%, followed by Johannesburg (76.8%), Tshwane (75.2%) and eThekwini (75%). The lowest is Buffalo City at 69.4% (Mathane, 2023), based on SACN, 2021). There is scope for South African cities to increase internet access to match and/or even surpass the current access level in terms of access to mobile telephones. Cities should strive to reach no less than 95% in this regard. More importantly, access to free Wi-Fi can assist cities to reach that end, thereby reducing the digital divide, and improving socio-economic justice and the right to information.

3.1.3 Data costs

Another policy issue is that there is unequal coverage, prohibitive data costs, and access to data remain a key challenge leading to low internet usage by poor communities (Lorini, et al., 2019; Muridzi, et al., 2021). In addition, municipalities do not set aside adequate funds (budgets) for smart technologies (Ncamphalala & Vyas-Doorgapersad, 2022). However, some of the metropolitan municipalities in South Africa have started to fund such initiatives (Manda & Backhouse, 2019). Sometimes, citizens are not aware of the digital platforms and tools created by municipalities; so they do not optimally use them. In most cases, municipalities do not reach out to communities and empower and teach them ICT skills so that they can use them. Citizens are also afraid of risks such as fraud, cyber-crime identity, theft, fraud, etc (Muridzi, 2018). Another issue relates to cybersecurity. Currently, South Africa has the third (3rd) highest number of cybercrime victims internationally (Duvenage, et al., 2022).

3.1.4 Digital divide

The National Development Plan (NDP) argues for the use of ICTs to transform South Africa (Manda & Backhouse, 2018). The NDP envisions that by 2030, South African society will be more dynamically connected through information technologies and that there shall be a vibrant economy built on knowledge (NDP, 2011: 190). The NDP further postulates that the "digital divide" must be undermined. There is the National Integrated ICT Policy Green Paper, 2014. The Green Paper appreciates that ICTs, if not properly managed, can cause further societal divisions. (National Integrated ICTs Policy Green Paper, 2014). Recently, the Department of Communications and Digital Technologies (DCDT), tabled the National Digital and Future Skills Strategy. This strategy aims to define the path for building a pool of digital skills for the economy, and to position and prepare South Africans to live in an era characterized by the pervasive and rapid adoption of digital technologies (National Digital and Future Skills Strategy in South Africa, 2020). Cities can play an important role in driving the vision of this strategy to reality.

3.1.5 Financing free municipal data (free Wi-Fi)

As indicated, in South Africa, unequal coverage, prohibitive costs, and access to data remain some of the key challenges leading to low internet usage by poor communities (Lorini, et al., 2019; Muridzi, et al., 2021). Ramokgopa (2018:226) found that one of the major weaknesses related to the municipal free Wi-Fi in South Africa is that there is to lack of clarity on the funding model. This can create an impression that access to the Internet is a luxury. Consequently, municipalities do not set aside adequate funds (budgets) for smart technologies, staff training, etc (Ncamphalala & Vyas-Doorgapersad, 2022). This view is also shared by Matobako (2016), who found that the city of Mangaung needs to allocate sufficient funds to cater for free Wi-Fi, related ICTs training, and bandwidth so that there will be quick and effective service to meet the information needs of communities. However, some of the metropolitan municipalities in South Africa have started to fund free Wi-Fi initiatives to address the issue of access to data, especially by poorer community members, as part of their socio-economic transformation agenda (Manda & Backhouse, 2019).

So, there is currently no credible funding framework for municipal free Wi-Fi in South Africa. Even though some of the metropolitan municipalities in South Africa have started to fund the free Wi-Fi initiatives (Manda & Backhouse, 2019), other municipalities simply cannot afford it. The issue of the funding framework/model for municipal digital programmes in South Africa should addressed as a matter of urgency. Key role players such as the National Treasury, Salga, Cogta, the FFC, and the DBSA should be tasked to develop an inclusive and comprehensive funding model for free municipal Wi-Fi in South Africa. Intergovernmental fiscal transfers and PPP funding models should be considered as part of the options. In some cases, municipalities may need to creatively use a combination of two or more approaches, depending on their realities and prevailing contexts.

3.1.6 The policy environment and digitalization of public services in South Africa

The following section discusses some of the policy instruments supporting digitalization of the public service operations in South Africa.

Public service transformation policy

Transformation of the public service has always been on the agenda in South Africa as early as the late 90's. Pursuant to this vision of a transformed Public Service, the White Paper on the Transformation of the Public Service (WPTPS) was promulgated in 1997. At the heart of this policy document are eight transformation priorities. These priorities are premised on a conviction that a transformed public service will lead to efficient service delivery for the citizens. The principle that is emphasized in this policy document is putting people first – Batho Pele (WPTPS, 1997).

Developmental local government policy

The Vision of the South African local government system as articulated by the White Paper on Local Government (1998) is one where municipalities play a central role in (re)building local communities so that they are part of a prosperous South Africa. This perspective resonates and finds expression with the values echoed by the concept of developmental local government. A critical part of the notion of the vision is municipalities working collaboratively with their local communities to find solutions to problems and improve the quality of life. Another critical thrust of the vision is ensuring inclusivity – making sure that no social groups are excluded and marginalized from the development process (White Paper on Local Government, 1998). This policy expression has implications for conceptualizing smart cities in South Africa. It implies that municipalities should intentionally endeavor to ensure that socio-economic justice is one of the key pillars of their digital strategies. Only then, can their smart cities be sustainable.

National Integrated ICT Policy

The National Integrated ICT Green Paper appreciates that ICT if not properly managed, can cause further societal divisions. So, it was predicated on the need to heed the imperatives of the Constitution, including that of constructing a society based on social justice. It promotes the idea of reducing the gap between those who have and those who do not have, the gap between those who are connected and those who are not disconnected. It affirms the role of ICTs in building inclusive societies and ensuring social justice. The Green Paper also sees ICTs as one of the ways to serve the needs of citizens, and by implication transform society, in particular for the needs of the poorest of the poor.

National Integrated ICT Policy White Paper, 2016

Anchored on 14 principles as foundational pillars, the National Integrated ICT Policy is framed from a rights-based perspective. Some of the values aspired by the policy include the right to access information, freedom of expression, the right to benefit equitably from the ICTs, the right to affordable communications, and the right to content that celebrates heritage. An important right is the right to universal access to ICTs, as well as the right to privacy and protection of personal information (National Integrated ICTs Policy Green Paper, 2014). The implications of this policy paper are clear for municipalities – their smart city interventions must promote inclusivity and cohesion. The critical pillars of the policy are digital access, transformation, and digital inclusion.

Municipal Corporate Governance of ICT Policy Framework

The Western Cape Department of Local Government, working in tandem with other key stakeholders developed the Municipal Corporate Governance of ICT Policy. The purpose is to institutionalize the ICT governance systems and align them with the planning agenda for municipalities (Municipal Corporate Governance of Information and Communication Technology Policy Framework, 2018). This policy framework has important implications for the municipalities. For most municipalities, ICT is not part of long-term strategy, it is seen just as an inwardly focusing support function. With the advent of the 4IR, cities need to appoint ITOs, whose role is to develop, conceptualize, and coordinate the implementation of an enterprise-wide digital strategy for a municipality. The ITO must be a suitably qualified professional, appointed at a senior executive level, reporting directly to the City/Municipal Manager.

National Digital and Future Skills Strategy in South Africa (2020)

Recently, South Africa, through the Department of Communications and Digital Technologies (DCDT), tabled the National Digital and Future Skills Strategy. This strategy aims to define the path for building a pool of digital skills for the economy, and to position and prepare South Africans to live in an era characterized by the pervasive and rapid adoption of digital technologies. The strategy acknowledges the 4IR. In this regard, the use of automated vehicles, cloud technologies, artificial intelligence, the Internet of Things, big data; etc. is encouraged as part of the new normal and building a digitally relevant socio-economic fabric going forward in the 21st century. This strategy has eight elements for building digital skills. It considers basic and intermediary skills, advanced skills, and industry 4.0 skills. It then talks about new skills required for the new world of work; as well as creating 4.0. (National Digital and Future Skills Strategy in South Africa, 2020). Cities can play an important role in driving the vision of this strategy to reality. It means that cities need to have a proper appreciation of the digital skills possessed by the communities they serve. Following that, cities need to develop developmental and capacity-building programmes to up-skill the communities, especially those from poor and disadvantaged backgrounds.

National Development Plan (NDP)

The National Planning Commission (NDC) has developed the NDP for South Africa. Many people view the NDP as an overarching plan for South Africa. Interestingly, whereas it adopts a tone that positions the use of ICTs to transform South Africa (Manda & Backhouse, 2018), some scholars believe that the NDP does not go far enough to express how this should be done. However, the NDP envisions that by 2030, South African society will be more dynamically connected through information technologies and that there shall be a vibrant economy built on knowledge (NDP, 2011: 190). The NDP further postulates that the "digital divide" must be undermined. The implications of the NDP for municipalities is that they can be part of this vision of building "connected" communities that are inclusive and economically vibrant. Interventions such as free Wi-Fi can go a long way toward localizing the realization of this vision.

3.2 The legislative environment and digitalization of the public services in South Africa

From a legislative point of view, Mathane (2022) suggests that several laws support digitalization in the public service in the South African context.

3.2.1 The Constitution

The Constitution, being the supreme law in the Republic of South Africa, defines the rights and duties of the citizens. It also commits South Africa to become a society based on social justice. When it comes to municipalities, the Constitution (specifically Chapter) 7 of the Constitution gives each municipality the right

to govern the local affairs of its community (RSA Constitution, 1996). Among the objectives of municipalities accorded by the Constitution is to provide basic services, promote socio-economic development, accountability, etc. In this regard, it can be argued that the Constitution provides an important legal framework for municipalities to design their digital smart city interventions that are grounded on principles of social justice.

3.2.2 The Municipal Finance Management Act

The Local Government: Municipal Finance Management Act, Act 56 of 2003, specifically provides rules, regulations, and procedures for handling the finances of municipalities in South Africa. Smart city programs can be very expensive, requiring more funding. In this regard, the Local Government: Municipal Finance Management Act (MFMA) advocates for sustainable management of the public funds at the municipal level. From a fiscal perspective, any municipality in South Africa that chooses to invest in smart digital platforms and/or technologies must ensure that they are affordable and budgeted for in terms of this Act as any spending that is not budgeted for and approved by Council is irregular and unauthorized.

3.2.3 The Municipal Structures Act and the Municipal Systems Act

The Local Government: Municipal Structures Act, 117 of 1998, is one of the most instrumental pieces of legislation in South Africa concerning municipalities. An important provision of this Act is all municipalities should include communities in their decision-making processes (RSA, Municipal Structures Act, 1998). So, in the spirit of this Act, municipalities can take advantage of using digital tools and platforms to engage their communities. However, whenever municipalities implement digital innovations, they need to make sure that communities are not left out owing to the digital divide caused by a lack of access to data, smartphones, computers, etc. Whereas the Municipal Structures Act focuses on the powers of municipalities, the Municipal Systems Act focuses on principles and processes for governing municipalities. So, the two pieces of legislation, in a sense, complement each other. Similarly, this Act also emphasizes the principle of community participation. The Act specifically requires municipalities to ensure that there are mechanisms to allow community participation. Another important principle of this Act is the principle of integrating planning.

3.2.4 The Spatial Planning and Land Use Management Act

The Spatial Planning and Land Use Management Act, Act 16 of 2013 (SPLUMA) is also one of the important pieces of legislation for municipalities to drive spatial transformation. In this regard, some of the principles promoted by this Act are inclusivity, efficiency, equity, etc. Other principles are good administration, spatial justice, efficiency, sustainability, and resilience (RSA, SPLUMA, 2013). A key implication of this Act is that any municipality in South Africa that chooses to invest in smart digital platforms and/or technologies must ensure that such investments will have the effects and outcomes of building and constructing inclusive cities, and communities. In other words, municipalities must not use digital technologies and innovations to entrench and reinforce apartheid spatial injustice in South Africa.

3.2.5 The Protection of Personal Information Act and the Promotion of Access to Information Act

The Protection of Personal Information Act, 2000, is also an important piece of legislation as far as digitalization and access to data and information. The object of the Protection of Personal Information Act (POPI Act) is to ensure the protection of citizens against the abuse of unfair and/or unjustified access to personal information. The Promotion of Access to Information Act, Act 2 of 2000 is also another important piece of legislation as far as digitalisation and access to data and information. This Act reinforces the right of access to information, which is constitutionally entrenched in South Africa. Before democracy in South Africa, the government was secretive, abusing its powers, and violating the informational rights of citizens. Now things have changed – the Constitution (Section 8) protects the rights of citizens. Section 32 (1) (a) provides that everyone has the right of access to information (RSA, Promotion of Access to Information Act, 2000). So, in designing, conceptualizing, and implementing smart digital tools, avenues, platforms, etc. senior municipal managers should ensure that the citizens' rights to privacy and access to personal information are not violated. As Oliveira, et al., (2020) point out, often digital innovations fail because the privacy of citizens is not protected. Muridzi (2018) admonishes African municipalities to develop security

protection measures such as those in countries like Korea. South African municipalities need to invest in cybersecurity to comply with the letter and the spirit of this Act.

3.2.6 The Promotion of Administrative Justice Act

Equally, the Promotion of Administrative Justice Act (PAJA), Act No 3 of 2000, outlines the principles that should undergird how administrative decisions and actions are taken by all state entities in South Africa. It says that all administrative actions and decisions must be procedurally fair, reasonable, and lawful. Importantly, other principles are accountability, transparency, openness, etc. This is about just administrative action. The Act stipulates that no administrative action or decision may adversely impact the rights of community members (RSA, PAJA Act, 2000). So, this Act also has significant implications for municipalities that may choose to use digital tools, platforms, and/or interventions. It simply means, among others, that municipalities should make sure that none of the smart digital interventions may have the effect of discriminating against some communities or prejudicing them in any way, manner, or form. The decisions about digital innovations should be done transparently, and the idea should be to promote administrative, and socio-economic justice for all residents.

4 CONCLUSION

Indeed, the Fourth Industrial Revolution has necessitated municipalities to review their systems, processes, and frameworks to enable them to be agile, and efficient, in responding to the needs and requirements of communities. Ordinarily, with the local government sector being regulated, municipalities need to be enabled by policy and legislation to execute their functions. This paper provided an overview of the policies, regulations, and legislation affecting municipalities in South Africa and analyzed the extent to which these policies and legislation enable or inhibit the rollout of digital technologies. On the policy side, the S.A. Connect Initiative is a good initiative to ensure that by 2030, South Africa will achieve 100% broadband access to everyone. The year 2030 is not far, and currently, approximately 68% of the South African population nationally, or 41 million, have internet access. There is a need to fast-track the progress in this regard. The issue of prohibitive data costs can be addressed through the provision of free municipal Wi-Fi programmes. This can also go a long way to reduce the digital divide as well.

On the legislative side, the Constitution commits South Africa to become a society based on social justice. From the perspective of the MFMA, municipalities just need to ensure that they budget adequately for investing in smart digital platforms and/or technologies; they must ensure that they are affordable and budgeted for; and avoid irregular and unauthorized expenditures. From the perspective of the Municipal Structures Act, public participation and active involvement of communities in planning for and rolling out digital innovations is very key. From the perspective of SPLUMA, the principles of spatial justice, good administration, and efficiency, are very vital to take care of when municipalities implement digital programmes. The rights of persons (e.g. privacy rights, dignity, etc) must be respected, in terms of the Protection of Personal Information Act, as well as the Promotion of Access to Information Act,

Finally, the authors conclude that South African municipalities do not have a deficit of policy and legislative frameworks to enable them to roll out digital technologies. This is to say, that the current policy and legislative framework is adequately sufficient to allow South African municipalities to roll out digital innovations. What municipalities need is the administrative and political will to execute. However, some areas need further attention. These include resolving the funding modalities, and developing supportive framework/s to guide municipalities so that as they roll out digital technologies, they don't risk sustainability imperatives.

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Regeneration of Urban Sites with Circular Economy Principles

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1 ABSTRACT

This research addresses the gap in effectively applying Circular Economy (CE) principles to urban regeneration, through the case study of Uetikon am See's redevelopment in Zürich. It introduces a Circular Economy in Real Estate (CERE) model to operationalize CE in urban planning, highlighting the challenge of translating CE concepts into actionable strategies. Focused on the "Chance Uetikon" project, the study demonstrates the need for strategic planning and stakeholder engagement to integrate circularity into the built environment effectively. By bridging theoretical principles with practical application, this research contributes to sustainable urban development, offering insights for achieving resilience and encourages closed-loop systems and circularity in spatial transformations.

Keywords: regeneration, economy, planning, city, sustainability

2 INTRODUCTION

A circular economy is an economic system that promotes the continuous circulation and sustainable use of resources and products at their highest value, while minimizing waste generation and environmental impact (EMF 2015). It is predicated on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. The concept of the circular economy represents a transformative approach to economic activity that aims to minimize waste, reduce resource depletion, and foster sustainable consumption and production (WEF 2014; EC 2012; EC 2014; EC 2020). It stands in stark contrast to the traditional linear economic model, which follows a "take-make-dispose" pattern, leading to resource scarcity, environmental degradation, and economic inefficiency (Kyrö 2020).

2.1 Brownfield recycling

As the circular economy begins with designing products and systems that are based on CE concepts and principles, it needs to consider a product or service (called here: a project) which encourages the development of closed-loop systems where flows are closed in the lifecycle perspective (Guerra et al. 2021).

On the other hand, urban regeneration emerges as a critical challenge and opportunity for the future urban development. This paradigm shift sees a reduction in new construction projects, which in turn, allocates more economic and spatial capital towards the revitalization of existing sites (Geisendorf 2017; Govindan et al. 2018). While considering the existing circular economy frameworks, a research gap has been identified in tools to transition urban areas and improve circularity at the city and regional scales.

Integrating brownfield redevelopment with circular economy principles is a promising approach to sustainable urban development, addressing both economic and environmental challenges by revitalizing underused urban areas through innovative, resource-efficient approaches. The following synthesis integrates findings from multiple studies to highlight the potential and challenges of such integration.

Arbab and Alborzi (2022) in their studies on sustainable regeneration of urban industrial heritage and redevelopment of urban brownfields, notably in the context of Tehran's Hakimiyeh neighborhood, provide a compelling basis for exploring the concept of recycling cities within the circular economy framework. These works underscore the significance of reimagining and repurposing abandoned industrial zones not merely as acts of preservation or aesthetic renewal but as integral components of a circular economy. By advocating for the sustainable regeneration of urban industrial heritage, these studies align with circular economy principles that emphasize minimizing waste, extending the life cycle of resources, and creating value through the restoration and adaptive reuse of existing urban fabrics. This approach not only addresses environmental challenges but also leverages historical and cultural assets to foster economic growth and social cohesion, illustrating a comprehensive method to recycling cities that harmonizes heritage conservation with circular economy objectives.

New Urban Ecosystem Services: The integration of bio-based land uses and Gentle Remediation Options (GROs) in brownfield redevelopment can significantly enhance urban ecosystem services, offering sustainable alternatives for managing contamination risks and restoring contaminated soil (Chowdhury et al., 2020). Similarly, the incorporation of green infrastructure in brownfield areas can provide important urban ecosystem services to local residents, contributing to improved quality of life in cities (De Valck et al., 2019).

Economic and Environmental Benefits: Brownfield redevelopment projects that include green infrastructure not only address urban sustainability but also offer economic benefits (Dorsey, 2003). The integration of urban agriculture and stormwater management in urban planning further enhances ecosystem services and supports urban resilience in the circular economy (Deksissa et al., 2021).

Challenges and Solutions: Despite the potential benefits, the integration of brownfield redevelopment and circular economy principles faces several challenges, including site contamination, financial and regulatory barriers, and the need for interdisciplinary collaboration (Cappai et al., 2019). Overcoming these obstacles requires robust policy support, strategic planning, community engagement, and the adoption of green technologies.

Policy and Governance: Improved legal regulations and instruments enhance the market chances of fallow areas, facilitating circular land management and supporting sustainable urban development initiatives (Ferber, 2011).

In conclusion, integrating brownfield redevelopment with circular economy principles offers a sustainable pathway for urban development, capable of revitalizing underused areas while addressing environmental and economic challenges. Achieving this integration requires a coordinated effort among all stakeholders, supported by innovative solutions and robust policy frameworks. This approach not only facilitates environmental remediation and the conservation of green spaces but also promotes economic revitalization and community well-being.

2.2 Goal

The goal was to develop a method to integrate CE in urban regeneration projects. How can regeneration projects be based on CE concepts and principles, which role plays a product or service which encourages the development of closed-loop systems and where flows in the lifecycle perspective are closed.

Starting from the CE principles, circular economy projects should emphasize resource efficiency by reducing the extraction of finite resources, such as minerals and fossil fuels, and promoting the use of renewable resources. It should encourage the development of closed-loop systems where flows are continually cycled.

It must represent a holistic and transformative approach to economic and environmental sustainability, aiming to break away from the linear "take-make-dispose" model and create a regenerative, waste-reducing, and resource-efficient system. Where applicable, consider the principle of sufficiency (Refuse, Share), typically the most effective strategy for minimizing depletion and pollution (Cetin et al. 2021).

2.3 Method

The approach involves:

- Analyzing the synergy between CE practices and urban regeneration;
- Applying these concepts to the Uetikon am See redevelopment: detailed case study analysis;
- Development of a CE model for green urban regenation projects.

3 STUDY AREA

The regeneration of the CU site, a previously industrialised area by the Lake Zurich, is analysed as an approach to brownfield redevelopment through the lens of circular economy principles. The project leverages its lakeside context through a large lake side park which extends with a comprehensive network of mobility - public open spaces as its structural backbone. This site has transitioned from a restricted industrial zone into a vibrant, multi-use district under the "Chance Uetikon" initiative - a collaborative effort by the municipality of Uetikon am See and the canton of Zurich up until 2021. The masterplan, comprising for interconected hubs linked by the park, the network of open space and mobility as illustrated in Figure 1 and

elaborated in Table 1, outlining a diverse mix of uses, including residential, commercial, services, education, recreation, leisure, and culture.

Fig. 1: Masterplan of Uetikon-am-See community with Residential Quarter (Wohnquariter), Community center/Mixed Use Area (Mitte), lakeside park (Seeuferpark), Cantonal School (Schulareal) and Harbour area (Hafen) (Masterplan Chance Uetikon, 2019)

Name	Picture	Description
1. Residential Quarter (Wohnquariter)		Ensures diversity through varying the apartments in terms of their location, standard of development, living space and type. Overall, on an area of 17300 sqm, 103 housing units and 85 condominuium were developed; Integrated CE priciples through ensuring diversity and embedding green spaces and natural elements for ecological benefits.
2. Community center / Mixed Use Area (Mitte)		Integrates CE principles in urban regeneration by repurposing historical architecture (“Düngerbau” building) and creating social cohesion through multifunctional spaces while preserving the local identity; “Düngerbau” is a central element of the development; through its public use, it is planned to become the social heart of Uetikon-am-See providing cultural events, small festivals, small business while conecting the old and new.
3. Lakeside park (Seeuferpark)		The lakeside park strongly contributes to a circular urban regeneration through Nature-based solutions It generates the ecosystem services and mitigates biodiversity loss at diferent scales; Increases the value of proximity residential and commercial developments.
4. Cantonal School (Schulareal)		In the east of the site, the Canton of Zurich is building a cantonal school with space for around 1,500 students and a vocational school with 500 students. An area that is coming to vibrant life.
5. Harbour area (Hafen)		The existing buildings are used by commercial or service businesses. In attractive locations, ground floors oriented towards the public are emerging. This area is envisioed as the new transport hub.

Table 1: Analysis of urban regeneration project (Masterplan Chance Uetikon, 2019)

4 RESULTS

The CU site's redevelopment into a new quarter at Uetikon-am-See give insights into how CE principles can be integrated into urban regeneration projects. The CU site's transformation into a mixed-use new quarter in Uetikon-am-See exemplifies the integration of CE principles into urban regeneration, offering a blueprint for future projects. The redevelopment is anchored by a strategic model centered around the lakeside park, which is part of a comprehensive network of public open spaces and infrastructure. This structural element enables four distinct mixed-use areas: a residential quarter, a community center/mixed-use area, a cantonal school, and a harbor area. Each of these hubs plays a pivotal role in fostering circular development by providing varied opportunities for the application of CE principles. The integration of CE principles across

these mixed-use areas is crucial for achieving sustainability and resilience in urban environments. By emphasizing nature-based solutions, resource efficiency, waste reduction, and the preservation of natural spaces, the project not only contributes to the social and environmental but also social and economic dimensions of sustainability. This case study contributes to the body of knowledge on successful CE management in urban regeneration, highlighting the importance of incorporating CE principles at every stage of development to create self-sustaining urban communities while following the elements highlighted below:

4.1 CE models

In each of the five projects several CE principles could be applied. In the residential quarter, the plan foresees demolition of the site and new construction of 188 living units. For the new construction of the residential area but also parts of the Cantonal school, the principle of Ressource Efficiency could be implemented. This includes an area efficient layout of the living units, applying the principle of Reduction by by minimizing the living area per unit. This approach must be carefully discussed with the property developer. Consequently, innovative renumeration models are needed for effective for sales marketing. Incorporating more green features in the residential area, but also in the lakeside park, makes the principle of regeneration feasable. However, one challenge remains as the land, formery a factory site is contaminated and unsuitable for trees and other vegetation.

The residential area should be developed with a specific focus on living concepts based on several generations. This provides a very good example to explore the principle Decelerate / Slow.

Evaluating the potential to reuse building components and/or materials of the exisiting buildings on a specific site exemplifies the principle of Circular Economy, specifically the Closing loop principle. By repurposing components and materials, we can close the loop, giving them new functions and uses.

Cooperation and Digitalization are two principles which most effectively can be integrated by cooperating with other stakeholders and by means of digital tools like digital twins. Implementing a digital building technology concept not only advances technology but also fosters efficient, sustainable schools. The collaboration with "Junge Tüftler" engages pupils to actively participate in energy management and emphasises the importance of a holistic educational experience. Building automation refers to the automatic control and regulation of functions within a building, including heating, air conditioning, ventilation, lighting, and shading (Junge Tuftler). As a key component of technical facility management, building automation aims to reduce energy and operating costs. It enables the automatic execution of functional sequences across different trades, based on predefined settings (parameters), and simplifies operation and monitoring.

This involves networking all sensors, actuators, control elements, consumers, and other technical units in the building. Processes can be integrated into scenarios, enabling intelligent and optimised interaction between the various components (Merz, 2016).

Building automation makes it possible to pursue and combine various objectives. These reach from reducing energy consumption through intelligent control; Demand-led control of heating, ventilation system or air conditioning; Flexible lighting control, Intelligent control of shading devices; Recording consumption data from heat meters, water meters, gas meters and electricity meters; Increased convenience, Load control based on consumption data recording; Increased safety through alarms in critical situations (Merz, 2016).

It is not only the resulting cost savings due to an energy-optimised building that are an incentive for a digitalised concept, but also the achievement of certification is a decisive reason for many building owners and users. With the help of nationally and internationally recognised certifications, sustainability aspects can be implemented in the real estate industry and the goal of sustainable properties can be achieved (Wagner, 2018).

The Düngerbau building, at the Chance Uetikon Areal, is envisioned a "Circular Community Hub” bringing together students, teachers, local residents, residents of the municipality of Uetikon, local businesses and associations. This hub aims to be a social connector within the community, offering to all stakeholders a space for various activities that enhance community life. (Suter and Jeanfavre 2023). This vision aspires to create an inclusive, flexible, and sustainable environment that fosters social ties within the community. The Circular Community Hub is a facilitator for collaboration, social innovation, and well-being for the

community of CU Areal. The principle of Regeneration guides the community center`s development, repurposing an old storage building for new uses.

Lake water energy provides a sustainable option for thermal networks or areas. This is done by collecting lake water a few metres above the lakebed using a strainer, an extremely large sieve. In the centre, a heat exchanger extracts heat from the lake water, which then serves as an energy source for a heat pump. The heat pump increases the temperature to the required level, usually between 40 and 65 °C. This means that the heat obtained can be used in the connected buildings for both heating and hot water preparation. In contrast to many other energy sources, lake water not only offers advantages in heating mode, but can also be used for cooling in summer. Here, the lake water, which is around 4 °C cold all year round, is used directly for room cooling through freecooling (ewz 2023). This provides another example of urban regeneration by exploiting local (energy) resources.

To conclude, the CE principles in urban regeneration are consolidated below:

- Resource Efficiency and Reduction in Housing: Focus on area-efficient layouts and minimized living space in the development of living units to optimize resource use.
- Deceleration and Multi-Generational Living: Promotion of slow living concepts through multi-generational housing arrangements, enhancing social sustainability.
- Regeneration Through Nature-Based Solutions: Integration of green features in residential areas and parks to facilitate ecological regeneration, even on previously contaminated sites.
- Material Loop Closure: Assessment and reuse of building materials and components from existing structures to close material cycles and promote resource circularity.
- Participatory Planning and Digital Integration: Strengthening cooperation with stakeholders and employing digital tools, like digital twins, for sustainable urban development and participatory energy management.
- Creating a Circular Community Hub: Transformation of the Düngerbau building into a hub for community engagement, embodying circular principles through inclusive and flexible use spaces.
- Innovative Sustainable Energy Solutions: Adoption of lake water-based thermal networks for heating and cooling, leveraging local natural resources for sustainable energy in urban regeneration.

4.2 Methods and tools

The methods and tools that were explored in the case study are:

- Scenario planning
- System Separation and design for adaptability
- Asset tracking
- Circular label strategy
- Food waste reduction
- Grey energy accounting

4.2.1 Scenario planning

In the case of Chance Uetikon, BIM could could be exploited by decision makers from an early design phase as well as during the operation. A digital twin in an early design phase would allow for visualization of the project before the shovel hits the ground (Dye, 2023). Moreover, different scenarios (use cases) could potentially be compared to identify the biggest possible overlap. The bigger the over-lap is the less extensive the construction work will be for future alterations. Additionally, the digital twin could include relevant information for the maintenance of the building and can be used during the planning phase of future conversions. To successfully plan different scenarios stakeholder management is extremely important. The real estate owner must be willing to invest upfront whereas the architect and the BIM team must be able to think about different use types and create the biggest overlap of the different scenarios possible.

4.2.2 System Separation and design for adaptability

According to Brand (1994) a building consists of six different building layers with different lifespans (Brand 1994). Whereas the interior is considered to have a lifespan of under 3 years, the structure of the buildings lasts up to 300 years. System separation as well as flexibility lead to better chances in reusing certain building layers. The Amt für Grundstücke und Gebäude des Kantons Bern (AGG) has created a guideline regarding the abovementioned issues. The aim of the guideline is to include the principles for separation as well as flexibility in all new developments as well as renovation. In order to achieve a higher flexibility, it defined the room height for new construction at 3.6 meters and the loading level of 3 kN (Amt für Grundstücke und Gebäude des Kantons Bern, 2013). The norming body ISO has created a document that defines principles, requirements as well as guidance regarding de-sign for disassembly (ISO, 2020). Such documentation will already be relevant in an early design phase as it gives the planning team more certainty regarding how to include these topics in the planning phase.

4.2.3 Asset tracking

Another important aspect of the circular concept on the area is to use assets more efficiently. Not far from the community centre is a school which is mainly in service during the day. As the Circular Com-munity Hub offers workshops and events in the evening, chairs, tables, whiteboards, cutlery, and so forth could be borrowed from there. To ensure that the location gets the desired amount of assets at the right time, a booking platform is relevant. However, the aim is to include that service as seemlessly as possible into the flow of the client. Systems such as Allthings (2022) allow to integrate needs of users along their customer journey, including the asset tracking and the booking of rooms as well as assets (Allthings Technologies AG, 2022).

4.2.4 Circular label strategy

Labels do help real estate owners in the communication with their stakeholders. Moreover, there are also studies, that argue that tenants are willing to pay a premium for sustainable buildings (Devine & Yönder, 2021). With the revision of their respective criteria, labels such as DGNB, SNBS, Minergie Eco will include the topic of circular economy in their scheme. Below, the most important criteria (in German) from DGNB are mentioned which could positively impact the assessment (Deutsche Gesellschaft für nachhaltiges Bauen - DGNB e. V, 2023).

4.2.5 Food waste reduction

The Düngerbau will be the central meeting point of the areal. As such, events will be hosted, and food will be offered. As a circular brownfield development, another focus will lie on the reduction of food waste. Technologies such as Artificial Intelligence can help to identify the sort of food waste which is generated. With it's plug and play solution, KITRO offers an overview of the food waste generated over time. These insights help to reduce the food waste over time by adjusting the supply.

4.2.6 Grey energy accounting

For the lake water use concept, the primary focus is on identifying the grey energy associated with the construction and operation of the lake water network, especially when compared to traditional methods like geothermal probes. This requires a thorogh calculation and analysis of the grey energy, which includes evaluating costs against those of geothermal probes. Such an analysis should be conducted through a life cycle assessment to accurately quantify grey energy and CO2 emissions.

4.3 Measuring circularity

Circularity is the core principle of the Circular Community Hub. The Circular Community Hub must have the ability to evolve with the needs of the stakeholders, both in the short and long term, while preserving limited resources. Additionally, the implemented strategies aim for economic, social, and environmental efficiency.

Aspects such as the dimensioning of the system, the achievable cooling and heating energy and the associated CO2 balance over the entire life cycle are to be considered in order to create a solid basis for decision-making. Another focus is on providing precise calculations to determine the required dimensions of the system and the achievable cooling and heating energy. The determination and calculation of the heating

and cooling requirements can be carried out based on the requirements outlined in chapter 4.2. This helps to evaluate the efficiency and performance of the lake water network in comparison to other technologies. Com-prehensive monitoring could be implemented during the operation of the system. This involves the continuous measurement of lake water and energy generation and their utilisation. This enables a real-time assessment of performance and contributes to the optimisation of opera-tion. The collection, measurement and evaluation of greenhouse gas emissions provide in-sights into the economic aspects and ecological effects over the entire life cycle of the lake water network.

The circularity of the measure should result in a value creation. To forster this it must be visible at three levels: at a social, economic, and environmental level. Additionally, for the value to be truly created for those three levels, a stakeholder centric approach must be taken. The value must be created for and with the stakeholders to be long-lasting (Tapaninaho & Heikkinen, 2022). Stakeholder centricity is at the heart of the Circular Community Hub, this is why the following types of value could be created.

4.3.1 Economic value

First, let's have a look at the most traditional value creation. Economic value creation can be observed for various stakeholders. The owners will get financial return on the buildings. Designers and planners, consultants, manufactures and facility management companies will get paid for their mandates. Additional jobs could be created thanks to the Circular Community Hub, such as kitchen chef or event managers for the scenario 2030, or care workers for scenario 2045. Hence, the Circular Community Hub could represent a local economic boost, which will make the local authorities and community more than happy.

The use of lake water is more economically and commercially viable if enough buildings or a neighbourhood can be connected. Thus, lake water utilisation projects often require local authority involvement and create an opportunity for citizens to actively participate in sustaina-ble developments. This raises awareness of environmental issues and the need for sustainable practices. Although the initial investment may be higher, such projects can lead to cost savings in the long term, especially if energy prices rise or environmental regulations are tightened (Impact Hub Lausanne, 2023).

Monitoring concepts are used to check the defined user requirements. With new software for technical monitoring, digitalisation makes it possible to optimise the settings and functionality of the system technology. With the help of monitoring, the functionality of different trades and systems becomes transparent. Potential for optimising the systems can be discovered and compliance with user requirements can be guaranteed. This ultimately leads to consistent, functional quality assurance and energy efficiency optimisation.

4.3.2 Social value

Then, social value creation might be the second most visible value creation of the Circular Community Hub project. A real community could be rise from the area which favours social cohesion. Additionally, community branding could contribute to the good reputation of the area. Cultural preservation of the history of the building but also of the new community's history can also be considered as social value creation. Finally, the flexible spaces of the Circular Community Hub could host educational workshop or health promotion initiatives as described in the various scenarios, which could contribute to the greater good.

A plan for digital labs for research on building technology in schools could include various elements to fulfil the needs of schools, teachers, and students. To integrate practical experience, a cooperation with the German organisation "Junge Tüftler" could be proposed. Thus, the teaching model for digital labs in schools in the field of building technology, in coop-eration with the organisation "Junge Tüftler", strives to provide a comprehensive educational experience.

4.3.3 Environmental value

Finally, the last value creation is about environmental value. The Circular Community Hub is designed to optimize the use of resources. Some materials will be reused, some reshaped and some even avoided thanks to scenario planning. Waste will be reduced or used as potential raw material to other projects. All these efforts contribute to the long-term sustainable viability of the Circular Community Hub and to reduce its environmental impact.

By using lake water as an energy source, the project can contribute to greater energy effi-ciency, as lake water can naturally store heat or cold. This leads to a more efficient use of energy compared to conventional systems. The project can also help to reduce greenhouse gas emissions by reducing the need for fossil fuels for heating and cooling systems (ewz, 2023). If implemented responsibly, the project contributes to the protection of water resources by ensuring that the water quality of the lake is not compromised and that sustainable extrac-tion rates are maintained. This promotes technological innovation and contributes to the further development of sustainable technologies.

4.4 Business model specifications

Through the specification of circularity of the different measures towards CE, an added value is generated. When planning the urban regeneration, it became clear that design thinking and system thinking approach can help to develop business models for the regeneration of urban sites.

Ideally, a thorough stakeholder analysis can help to identify the stakeholders that are needed for the business model spcifications. Value will be created in the economic, social, as well as environmental pillar. Economic value will be created for different stakeholders such as real estate owners, planning teams and operator by activating an unused building. Social value will emerge by bringing together a community and offering events. Moreover, the identity of this location can be preserved. By reusing building materials and sharing assets on the areal, environmental benefits can be created.

The implementation of circular principles also requires a shift in business models. The most prominent business model are sharing platforms or products as a service, where light is for example rented instead of buying the infrastructure for light. Additionally, reused or recycled products can be used as the raw materials for the Düngerbau. In order to ensure the flexibility of the building, however, the physical connections between elements should gain special focus to ensure demountability.

5 DISCUSSION: DEVELOPMENT OF A CE MODEL FOR GREEN URBAN REGENATION PROJECTS

Based on the case study a method was developed and is presented that is based on four pillars:

- Determination of CE concept and alocation in the Circular Economy in Real Estate (CERE) model
- Choice of a method and a tool for the chosen CERE model
- Determination of data needed to measure the circularity, including stakeholders identifation
- Specification of business model by using Sustainable Business Model Innovation (SBMI) to specify all input needed.

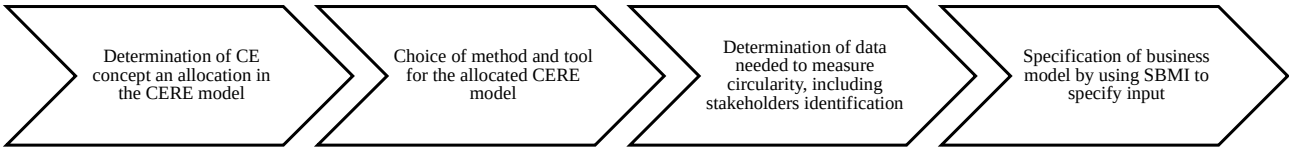

Fig. 2: CERE model for urban sites

5.1 CE concepts

Based on an analysis of existing CE models, a new model tailored to the real estate lifecycle management was proposed [4]. Here, the principle should be allocated in the CERE model.

Principle	Description
Ressource Efficiency	Reducing Entropy and Optimizing operation
Regeneration	Improving the state of human and eco-logical systems through the use of renewable and healthy resources
Reduce	Restricting resource flows throughout the life cycle of buildings (Share, Reuse, Repair)
Decelerate/slow	Slowing down resource flows by intensifying use and extending useful life
Closing	Returning resources to the cycle at the end of their life

Cooperation	Fostering collaboration between supply chain actors
Digitalization	Efficient handling and systematic collection of information and data over the entire life cycle of a building to increase transparency, traceability and optimization of processes

Table 2: Basis of CE principles in CERE model [4]

Regeneration is one of the CE principles and is based on improving the state of human and ecological systems by using renewables and healthy resources.

5.2 Methods and tools

In practice, the circular economy encompasses a broad range of industries, from manufacturing and construction to fashion and electronics. It involves adopting innovative technologies, material recycling, reverse logistics, and sustainable procurement practices to close the loop on product lifecycles. This step involves choosing a method and a tool from real estate lifecycle which you would apply for your case. This step should be supported by giving the reasons for the choice and specification of the information need to use the tool and method. There are emerging tools and methods that can be explored. They differ in how to quantify the circularity of a proposed measure.

5.3 Measuring circularity

Beyond waste reduction, the circular economy seeks to regenerate natural systems. This includes promoting regenerative agriculture, reforestation, and sustainable land use practices to restore ecosystems and biodiversity. The urban developer should explain how he/she would measure the circularity of his/her project. It starts with listing the data needed to measure the circularity, which stakeholders are needed to involve, and which values are created in the project.

Table 3 shows emerging tools for measuring circularity. It will be interesting to explore further the relation between measures on the existing building stock and the materials, components, and buildings already in use and new constructions and their impact on the future life period of the urban site. In this sense, each urban development has two aspects to measure the circularity, a pre-use and post-use circularity. More work is needed to develop these methods further.

Tool	**Developer**	**Description/Focus**
Circularity score (SC)	RWTH Aachen University	Measures the circularity of materials and products, focusing on their lifecycle and reuse potential.
Concular Circularity Performance Index (CPX)	Concular	Evaluates the circular performance of building materials, emphasizing sustainable resource usage.
DGNB Circularity Index (DGNB CI)	German Sustainable Building Council (DGNB)	Assesses buildings for their circularity, including material recyclability and resource efficiency.
EPEA Circularity Passport Buildings (CP)	Environmental Protection Encouragement Agency (EPEA)	Certifies buildings on their circular design and construction, based on Cradle-to-Cradle principles.
IBO Disposal Indicator (EI)	Austrian Institute for Healthy and Ecological Building (IBO)	Quantifies the environmental impact of building materials at the end of life, promoting recycling.
Madaster Circularity Indicator (MCI)	Madaster	Tracks the circularity of building materials to improve waste management and recycling strategies
Urban Mining Index (UMI)	Bauhaus-Universität Weimar	Analyzes buildings as material reservoirs for future use, supporting the urban mining concept
Recycling Graph method	Schwede, D. and Störl, E. (2016)	Provides a method to calculate the potential for material recycling in construction projects
Circularity Index BBSR	Federal Institute for Research on Building, Urban Affairs and Spatial Development DE	Analyze the circularity of construction products in the German ÖKOBAUDAT database (Dräger et. Al. 2022)

Table 3: Emerging tools for measuring circularity

5.4 Sustainable Business Model Innovation (SBMI)

The circular economy is gaining global momentum, as various organizations, governments, and businesses actively pursuing circularity to tackle urgent environmental challenges, lower carbon emissions, and foster economic resilience in an increasingly resource-constrained world. The final step involves specifying the project`s business model. To achieve this, the SBMI framework can be utilized, requiring specific inputs. These include defining the value creation process, identifying stakeholders and their roles in the project, and outlining the market opportunities for the business concept.

At the core of effective circular business innovation is design thinking, a methodology that emphasizes human needs, empathy, and collaboration. Design thinking encourages businesses to start with a deep understanding of user needs and aspirations, rather than relying solely on technical specifications or market

trends. This empathy-driven approach helps businesses identify opportunities to create products and services that are not only sustainable but also valuable to their customers. Design Thinking is a human-centered approach to problem-solving that emphasizes empathy, creativity, and iteration. It involves understanding the needs and desires of users, brainstorming solutions, prototyping ideas, and getting feedback from users (Schön 1997). Design thinking also promotes a collaborative process, bringing together diverse stakeholders, including designers, engineers, marketers, and customers, to co-create innovative solutions. This cross-functional collaboration fosters a shared understanding of the problem and enables the development of solutions that address both environmental and human needs (Lawson 1997).

Once a sustainable business innovation has been identified and a CE concept has emerged, lean innovation provides a framework for rapidly prototyping, testing, and iterating on product or service ideas. This iterative approach helps businesses avoid costly mistakes in the later stages of development and ensures that their circular solutions meet the needs of both users and the environment.

The Lean Innovation Model was developed in 2014 with the aim to become a reference for a successful, coherent, and integrated implementation of lean thinking in innovation and product development. It considers, both the technical aspect that should be considered in lean product development process itself, as well as the ‘soft’ aspect which is indispensable for a successful implementation (LIM 2014).

6 CONCLUSION

This study contributes to the field by providing a practical application of CE in urban regeneration. It innovatively combines CE principles with urban redevelopment, showcasing how traditional "brownfield" sites can be transformed into sustainable, vibrant communities. This approach represents a significant shift from the linear economic model, offering a replicable model for sustainable urban development driven by Nature-based solutions.

In view of the comprehensive analysis of sustainable concepts at Uetikon Cantonal School, the introduction of a regeneration concepts, the lake water use concept and the digital building technology concept are pioneering measures. These initiatives not only reflect the idea of a circular economy, but also mark significant steps towards a future-orientated urban regeneration approach.

The integration of a CE models demonstrates a conscious use of resources and a clear positioning against the linear economy. The proposed method and tools not only offer efficient planning options, but also emphasise the emotional value of sustainability for the identity and history of the environment.

Nevertheless, our findings underline the effectiveness of this CERE model of energy generation and utilisation in the context of sustainability and the circular economy.

The implementation of a CE concepts often goes beyond technological progress and creates efficient, sustainable urban sites. The collaboration with stakeholders to actively participate in CE planning management emphasises the importance of a holistic planning experience.

This study contributes to the field by providing a practical application of CE in urban regeneration. It innovatively combines CE principles with urban redevelopment, showcasing how traditional "brownfield" sites can be transformed into sustainable, vibrant communities. This approach represents a significant shift from the linear economic model, offering a replicable model for sustainable urban development driven by Nature-based solutions. This research stands out in the realm of urban redevelopment by redefining the transformation of traditional brownfield sites. It extends beyond conventional approaches, exploring novel possibilities for real estate products.

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🏆 *reviewed paper*

Revitalising our Urban Landscapes: A Call for Territorial Regeneration

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1 ABSTRACT

The paper addresses the urgent need for a paradigm shift in response to the escalating climate crisis. The paper draws on Jem Bendell's concept of Deep Adaptation, emphasizing the inadequacy of traditional adaptive measures in the face of unprecedented environmental risks. (Bendell, 2018)

The central theme revolves around the imperative to transition from a fossil-fuel economy to a post-carbon society. It underscores the severity of the biosphere crisis, as evidenced by alarming biodiversity loss and the exponential increase in global fossil fuel consumption. The urgency emphasized in Bendell's call for action since 2018 underscores the need for a radical reevaluation of conventional adaptation paradigms. The transition proposed is not only quantitative but also qualitative, demanding a profound societal transformation.

The paper introduces the concept of "Territorial Transition" as a strategic approach to climate-oriented systemic change. This involves spatial strategies that integrate climate potentials and large-scale considerations, aiming for long-term coexistence of all species. It challenges the conventional notion of adaptation and advocates for relinquishing unsustainable practices. (Armengaud et al., 2023)

Additionally, the paper delves into the significance of moving beyond mere resilience to embrace regeneration actively. The call for regeneration goes beyond mitigating harm; it demands active participation in the healing of ecosystems through regenerative agriculture, reforestation, and biodiversity preservation.

The acknowledgment of inevitability is a crucial aspect of Deep Adaptation, recognizing irreversible impacts of climate change. The essay emphasizes the need for agile planning and design in the face of uncertainty, questioning traditional practices and advocating for both immediate territorial transition and ecological regeneration.

The interdisciplinary perspective is highlighted through the Berlin Declaration of the German Academy for Urban and Regional Planning, urging a shift from anthropocentrism to an eco-centric framework. The author urges a shift in systemic thinking and action, recognizing the interconnectedness of urban and rural areas in a spatial network. (DASL, 2022)

In conclusion, the paper emphasizes the necessity for architects, urbanists, and planners to move beyond anthropocentrism and engage in territorial regeneration. This involves reimagining urban spaces as dynamic ecosystems that actively contribute to the well-being of both humans and the more-than-human world. The call is for a profound shift in discipline, from building to regenerating, with territorial regeneration being the key to revitalizing landscapes and addressing the urgent challenges of climate change.

Keywords: Regenerative Design, Deep Adaptation, Territorial Transition, Sufficiency, Uncertainty

2 FROM KNOWLEDGE TO ACTION

20 minutes of climate protest have achieved more than 20 years of scientific research. With this sentence, the Viennese climate researcher Reinhard Steurer opened his lecture "Overcoming Fake Climate Protection" at the TU Graz. (Steurer, 2023) He thus addresses accurately the painfully discrepancy between existing knowledge about the environmental state of the planet and the political and societal readiness to act. The complacency of our previous ways of thinking and acting in the face of climate chaos can no longer hold. We stand at a precipice where a radical rethinking of our relationship with the natural world is our only viable path forward. Now we need to decide.

The challenges and uncertainties of our time such as climate change, biodiversity loss or resource scarcity, Deep Adaptation[1] emerges as a compelling necessity. Deep Adaptation is a framework from Jem Bendell – a British sustainability researcher and a professor of sustainability leadership at the University of Cumbria – that deals with the challenges of climate change and the need for adaptation. It emphasizes the necessity to prepare for the worst and to prepare for potentially radical change in social, economic, and ecological systems. Climate change is a reality that already has tangible effects on our world. (Bendell, 2018) Given the urgency highlighted by Bendell since 2018 in his call for preparing for the worst and taking swift action, it becomes evident that in an era of unprecedented environmental risks, the conventional paradigms of adaptation no longer suffice. We need to rethink.

The big challenge humanity is facing today is the transition from a fossil-fuel economy to a post-carbon society. The transition process relates the actions to be undertaken to the time required and aims not only for a quantitative but also for a qualitative transformation.

But we are still on the wrong track. We further remain in a serious biosphere crisis, that is strongly linked to climate change and it's becoming even worse. The Living Planet Index report from 2022 shows a massive biodiversity loss in the last 50 years. It says that "[…] studied animal populations have seen an average relative decline of 69% since 1970" (WWF, 2022). (See Fig. 3) Further data shows also that we are responsible for a continued exponential increase in fossil fuels worldwide over the last 20 years. (see Fig.1) And the latest IPCC report is emphasizing the urgency of taking action to mitigate climate change, for achieving the Paris Agreement's 1.5-degree target. It necessitates comprehensive and immediate measures to reduce greenhouse gas emissions. But if we look at the last five years since the concept of Deep Adaptation emerged the "[…] probable, inevitable or unfolding collapse of industrial consumer societies, due to the direct and indirect impacts of human-caused climate change and environmental degradation" doesn't seem so far (Bendell und Carr, 2021). We have the knowledge about the dramatic climate and environmental situation since at least 50 years, now we need to act.

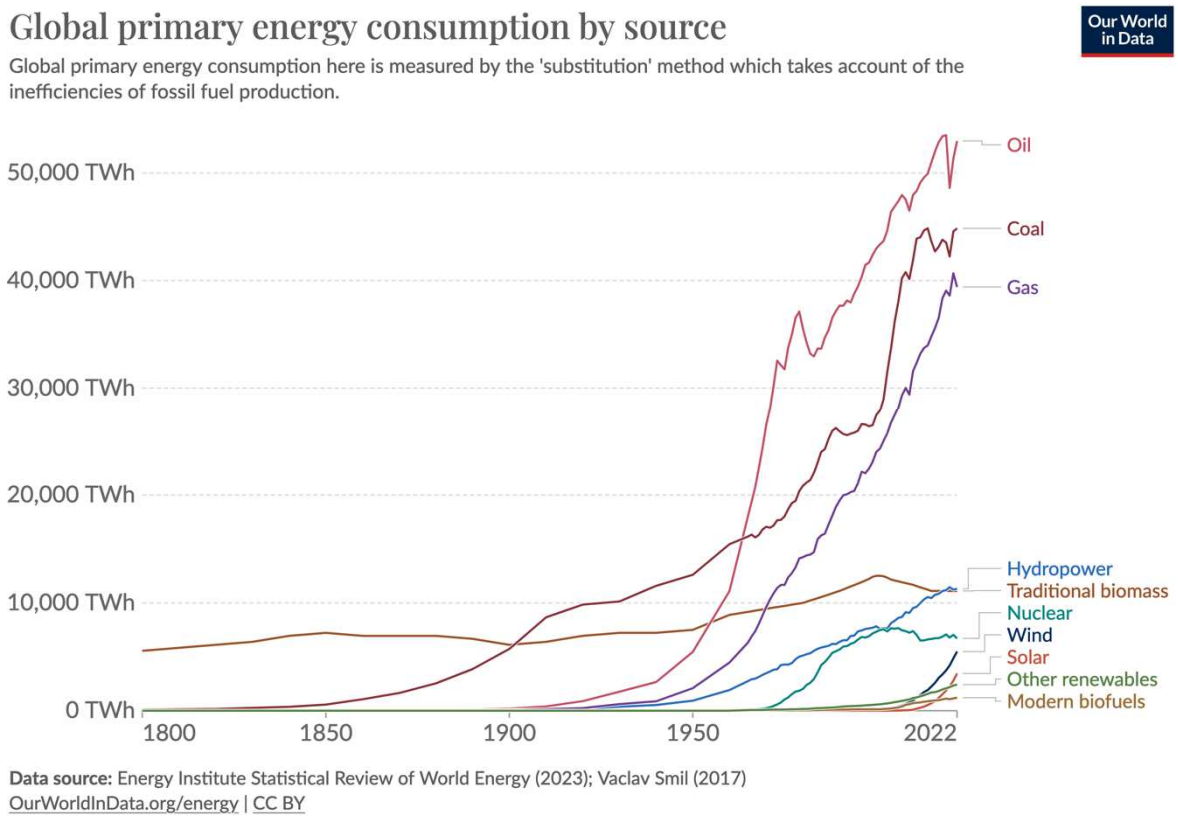

Fig. 1: Energy Institute Statistical Review of World Energy (2023); Vaclav Smil (2017)

[1] The article "Deep Adaptation: Navigating the Realities of Climate Chaos" was published in July 2018 by Professor Jem Bendell. The article emerged against the backdrop of growing concerns about the speed and severity of climate change and the limited progress in mitigating greenhouse gas emissions.

3 FROM ADAPTATION TO TERRITORIAL TRANSITION

Adaptation, in its traditional sense, often implies incremental adjustments within the existing frameworks. We've believed that technological innovations and minor policy changes would suffice to mitigate the impending climate catastrophe. However, these solutions have proven woefully inadequate. The scale and urgency of the climate crisis demand an entirely new perspective. Territorial transition signifies a comprehensive and systemic shift in the way we interact with our environment. It involves the relinquishment of unsustainable practices and the embracing of regenerative and sustainable alternatives. It calls for a profound reevaluation of our consumerist culture and an earnest commitment to fostering resilience in the face of unpredictable climate disruptions. We must redefine our priorities, with the well-being of the planet and its inhabitants taking precedence over short-term profits and convenience. We need to worry.

Moreover, this transition also entails a reconciliation with the irrevocable losses we face. Some damage is already done, and as we adapt to our rapidly changing world, we must find ways to see and remember the species we've lost and the ecosystems forever altered. This collective memory can be a catalyst for change, fostering a deeper connection with nature and reinforcing our commitment to preserving it. (See Fig. 2) Now we need to remember.

Territorial transition is a process that starts from the necessity and urgency of climate-oriented territorial and systemic change. To reaching the common goal of becoming climate-positive it offers quantitative metrics but more importantly strategical spatial approaches, which are both climate-oriented and large-scale. Transition combines the climate potentials with spatial qualities and creates multi-scalar, measurable added value to make possible a long-term existence of all species. (Armengaud et al., 2023) Now we need to transition.

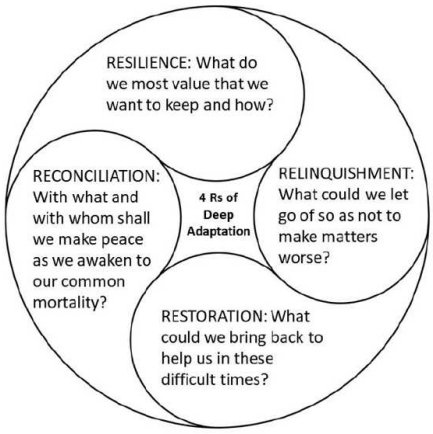

Fig. 2:The Four Rs of Deep Adaptation: The concept of Deep Adaptation is offered with a framework of four questions to support people's consideration of implications of anticipating societal collapse

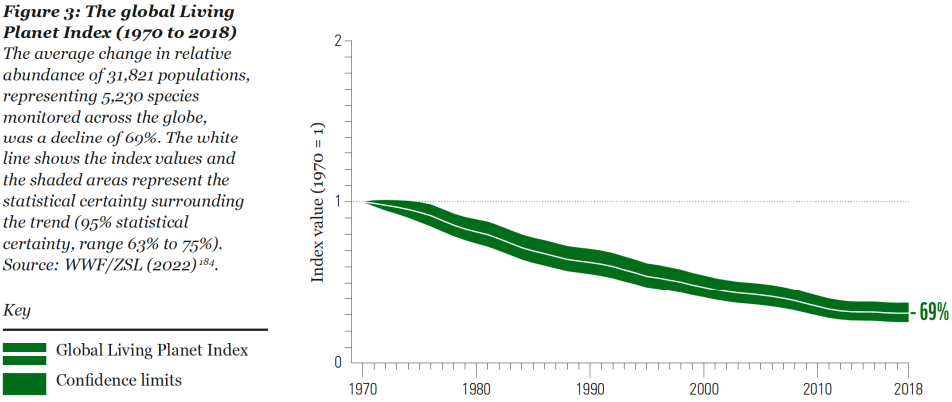

Fig. 3:The global Living Planet Index (1970 to 2018) The average change in relative abundance of 31,821 populations, representing 5,230 species monitored across the globe, was a decline of 69%. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (95% statistical certainty, range 63% to 75%). Source: WWF/ZSL (2022) 184.

4 FROM RESILIENCE TO REGENERATION

Another key aspect of Deep Adaptation is the emphasis on resilience. The concept underscores the need to strengthen the resilience of societies and communities to better confront the growing challenges of climate change. This resilience extends across social, economic, and ecological domains, with the aim of enhancing adaptability to these changes. But resilience alone is not enough. To reverse the damage, we've inflicted upon our planet, we must also embrace regeneration. Regeneration embodies the essence of rebirth, restoration, and renewal. It is a call to action, urging us to not only mitigate the harm we have caused but to actively participate in the healing of ecosystems. It necessitates regenerative agriculture, reforestation, rewilding and the preservation of biodiversity. It is a commitment to not just “do less harm” but to “do more good” for our planet. In the face of climate chaos, regeneration is not mere concept; it is our guiding principle, our beacon of hope. It reminds us that even in the midst of chaos, we possess the power to adapt and to heal. Now we need to regenerate.

5 FROM INEVITABILITY TO UNCERTAINTY

The third critical point in this concept is the recognition of inevitability. Deep Adaptation acknowledges the fact that some impacts of climate change may no longer be reversible. This awareness necessitates our adjustment to a world where certain changes are unstoppable, and it calls for taking appropriate measures to cope with these unavoidable changes. Tipping points in climate change (such as melting of the Arctic ice sheet, changes in ocean currents, or loss of permafrost) are critical thresholds at which the Earth system can abruptly and often irreversibly transition to a new state. These points mark critical changes in environmental conditions that affect the stability and functioning of our planet. Crossing these thresholds could lead to drastic impacts on climate, ecosystems, and human society. This volatile eco-systemic dynamic asks for agile forms of planning and design, questioning traditional routines and practices. Now we need to prepare.

Climate catastrophes, hazards, health crises or humanitarian disasters can change spatial demands and necessities within days. Transitions are situations of high uncertainty, doubt, and contradictions. They question the velocity of dynamic urban or economic developments, advocating for an immediate territorial transition but at the same time for slowness as a valuable asset for ecological regeneration. Now we need to cherish.

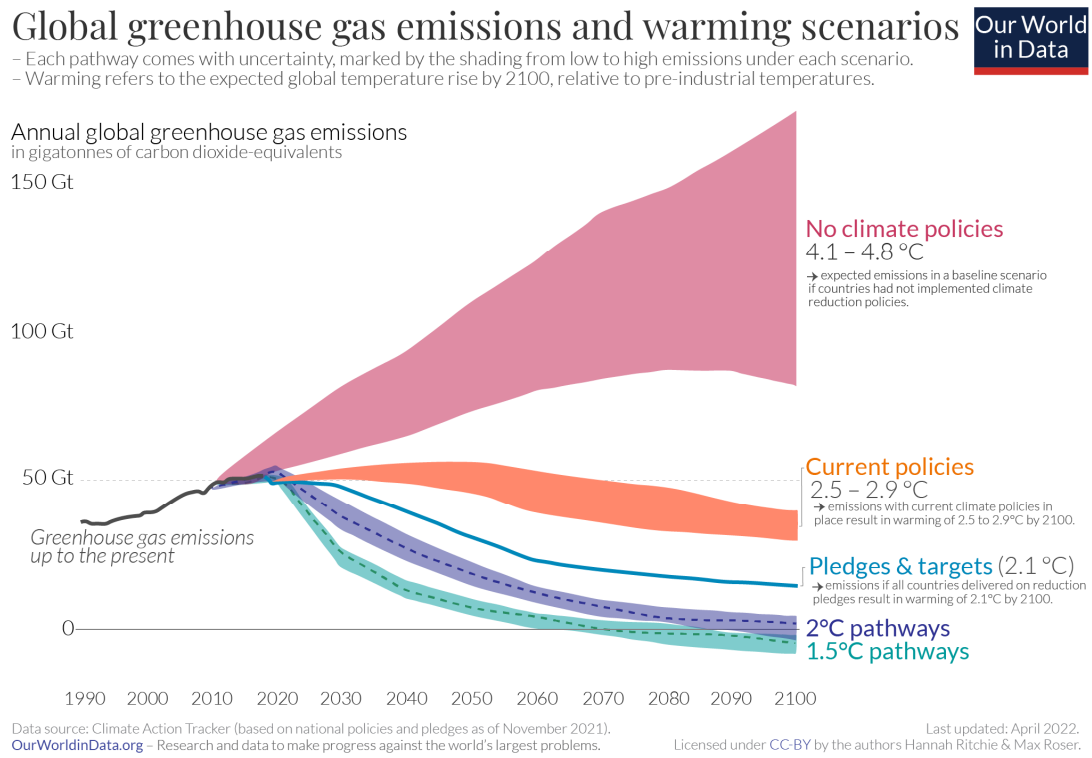

Fig. 4:The existing climate policies will result in a reduction of emissions, but the pace of reduction is insufficient to meet global targets.

6 DISCIPLINARY SHIFT

In the Berlin Declaration of the German Academy for Urban and Regional Planning with the title “Our Cities and Regions: What Must Change – How We Must Change” (DASL, 2022) the Academy redefined its societal responsibility for the future of cities and regions. The Berlin Declaration is intended as a political stimulus and as a self-commitment. The Declaration puts out first that a new balance in the relationship between humans and nature is needed. Leaving behind traditional concepts of domination over nature, perpetual growth, and the primacy of technical solutions that do not rely on sustainability (no more resources taken than added) and sufficiency (produce differently, use resources more efficiently, and consume less). This demands a not only a cultural shift but a shift in systemic thinking and action, recognizing that urban and rural areas are interconnected through various metabolisms and must always be understood as a spatial network, in order to establish a circular economy. Now we need to change.

However, while some progress is being made compared to a scenario with no climate policies, we are still far from achieving the international targets set for mitigating climate change. The existing climate policies will result in a reduction of emissions, although the pace of reduction is insufficient to meet global targets. (See Fig. 4) Now we need to hurry.

We as architects, urbanists, landscape architect and planners need to leave anthropocentrism and reimage urban spaces as dynamic ecosystems that actively not only contribute to but also really care for the well-being of both human and the more-than-human world. This horizontal approach acknowledges the interdependence between cities and their surrounding environments, advocating for a shift towards an eco-centric framework that give equal importance to the welfare of the entire planet and its diverse inhabitants. Now we need to connect.

So how do we need to change our discipline? How can Post-sustainable[2] architecture and urbanism look like? Benedikt Boucsein puts it like this: “The egalitarian city is the city that doesn't get built” (Boucsein, 2021). We need to stop building and start regenerating. Territorial regeneration, in this intricate relation of transitions and territorial systems, is the key to revitalizing and restoring urban and rural landscapes. It is the promise of healing ecosystems, of reconnecting fragmented habitats, and of reclaiming spaces for both natural and human communities. Spatial regeneration involves rewilding urban areas, restoring degraded ecosystems, and breathing life back into once-barren lands. It is a journey of profound transformation, one that encompasses our relationships with the natural world, our fellow human beings, and future generations. Caring for our planet means putting the living systems in the urban-rural continuum at first place. Deep territorial regeneration is crucial in order to at least have a chance to invert climate change and ecosphere crisis. Now, we need to truly care.

Fig. 5:Fossil fuel infrastructures and natural co-habitats. Source: Anna Positano

[2] Post-sustainability suggests that conventional sustainability efforts, as implemented in politics and the economy, are insufficient to address pressing issues such as climate change, resource depletion, and social injustices. It emphasizes the need for more radical approaches.

7 CONCLUSION

In view of the available evidence and the increasing urgency of global environmental issues, the conclusion is clear: territorial regeneration is an indispensable strategy for overcoming the complex challenges of the 21st century. Climate change, the loss of biodiversity and the scarcity of natural resources require not just marginal adjustments, but a fundamental reorganisation of our approaches. The concepts presented, such as regenerative design, territorial transition and sufficiency, offer not only theoretical approaches but also concrete frameworks for transformative implementation.

The demand for territorial regeneration is not in contradiction to technological innovation or economic efficiency, but opens up an evolutionary path for a sustainable, systemic transformation. The transition from a fossil fuel economy to a post-carbon society requires not only quantitative but also qualitative changes. A comprehensive reassessment of our consumer behaviour and a serious commitment to promoting resilience to unpredictable climate disruption are essential.

Recognising the inevitability of some impacts of climate change requires adaptive planning and design that relies on agile forms of adaptation and uncertainty management. The introduction of a horizontal, eco-centric perspective in urban planning and architecture marks a paradigm shift that emphasises the interdependence of urban and rural areas. The shift to post-sustainable architecture requires not only a cultural but also a systemic change that emphasises the need for a spatial network to establish a circular economy.

However, given the prevailing pace of climate change and the shortcomings of existing climate policies to date, urgency is required. Transforming our thinking and actions away from anthropocentric models towards environment-centred approaches is essential. Territorial regeneration is not just a concept; it is the way to revitalise and restore urban and rural landscapes. It is a commitment to heal ecosystems, reconnect fragmented habitats and restore space to both natural and human communities. Caring for our planet requires not only knowledge, but above all concrete action. Now is the time to turn these words into effective action and pave the way to a sustainable and regenerative future.

8 REMARK

Parts of this essay were produced with the assistance of an AI. The purpose of using the AI here is to assist in researching relevant information and to broaden the scope of the discussion.

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🏆 *reviewed paper*

Security and Compliance in Cloud Environments

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1 ABSTRACT

Security and resilience of smart city infrastructures and operations is one of today's most relevant and challenged topics of smart city agendas in times of increasing cyber attacts and ubiquitous digital networks and data driven processes in all aspects of smart city planning and operations. Cloud environments play today and increasingly tomorrow a central role in smart city's IT architectures and infrastructures.

According to the reviewed literature on the subject of cloud and security, the main gap or problem is that while cloud provides a number of advantages and benefits, it also presents risks and challenges for businesses and organizations (Vacca, 2021).

The key challenge is the risk associated with the user privileged accesses. It centers on the problem of inappropriate access control, which can lead to data leakage and unauthorized access of stored information, disruption, and compliance difficulties (Tamunobarafiri, et al., 2019).

Further, it is observed during that one of the biggest challenges to all concepts related to cloud, security and compliance is monitoring and ineffective incident response, which is essential for maintaining security in cloud and hybrid environments (Cybellium Ltd, 2023). It is important that organizations ensure that they establish a clear, well-structured incident response plan and conduct regular security testing internally, or with support from third-party vendors (Bruinsma, 2023).

In addition, the lack of thorough and practical approaches to resource scalability and cost optimization is one of the major research gaps in the field of cloud computing. Companies seek solutions that are capable of handling the whole range of resource scalability and cost optimization challenges, with regard to maintaining security and compliance, as current options are frequently inconsistent and fragmented (Verma, Cherkasova, & Campbell, 2011; Zhang, Cheng, & Boutaba, 2010; Calheiros, Ranjan, Beloglazov, DeRose, & Buyya, 2011).

Finally, raising awareness and educating stakeholders and staff about the security protocols and cloud governance framework is another crucial challenge. Having training sessions, documentations, and establishing clear communication guidelines are important for organizations with the sole aim of reducing the security-related risks (Spair, 2023; Munir, Al-Mutairi, & Mohammed, 2015).

The research objectives of this thesis revolve around some critical issues within the sphere of security and compliance in cloud and hybrid environment. The study aims to comprehensively shed light on the implications of excessive global administrative rights within organizations, investigating the potential risks and vulnerabilities associated with such practices. It also seeks to identify effective approaches for achieving a robust alignment between incident response and monitoring mechanisms, ensuring a proactive and coordinated approach to security threats. Additionally, the research will recommend strategies to enhance stability and optimize costs in context of information security, addressing the challenges that organizations face while maintaining security measures. Lastly, the study will explore the factors that impact the effectiveness of security training programs, providing awareness into how smart city administration and other organizations can better prepare their staff and workforce to mitigate security and compliance risks.

Keywords: smart city, governance, compliance, security, cloud

2 RESEARCH DESIGN

To address the central research question, how risks and challenges for businesses and organizations, could be mitigated and controlled, a set of research objectives as well as related resarrch questions arised.

To address the questions, accomplish the research goals, and fill in the research gaps, a qualitative research design will be used in this study. Because the study's subject matter is delicate and complicated, requiring a high degree of accuracy, dependability, and user satisfaction, the qualitative design approach is the most

appropriate choice. By encouraging respondents to elaborate on their responses and better understand their requirements and expectations to close the gaps in the areas linked to security and compliance in cloud and hybrid environments of a business, a qualitative research analysis will help foster openness. Content analysis will be the analytical technique used. Interviews will be used to gather data, which will then be conceptually analyzed, recorded, and transcribed. Qualitative research designs are typically grounded on people's lived experiences and conducted in natural settings. To finish the paper and comprehend the needs, this strategy is crucial. Nonetheless, the data's ability to be broadly used is limited by the research methodology (Marshall & Roassman, 2016).

Sr. No.	Research Objectives	Research Questions
1	Investigate the implications of excessive global admin privileges	What are the key challenges and benefits of implementing standardized security controls?
2	Identify approaches for achieving a robust alignment of response and monitoring	What are the critical factors in achieving a robust response and monitoring alignment?
3	Propose strategies for efficient resource stability and cost optimization	How can organizations achieve resource scalability and cost optimization while maintaining security and compliance in cloud environments?
4	Explore the factors influencing the effectiveness of security training programs	How can training programs be enhanced to improve employee understanding of security risks and best practices in cloud and hybrid environments?

3 LITERATURE REVIEW

3.1 Identity and Access Management

3.1.1 Challenges of implementing standardized security controls

Establishing standard security controls, protocols and procedures may be a challenging endeavour for companies, which frequently face a slew of obstacles. One key difficulty for numerous companies is a lack of awareness of security hazards. Given their lack of knowledge, companies struggle with the assessment of security measures that are the most significant and corresponding execution. They may not protect themselves adequately from new and developing threats because of an absence of understanding and awareness of the hazards and risks, which could end up in security threats and breaches (Rob S., 2023). The next obstacle is insufficient availability of resources. Setting up and upholding adequate security measures may be laborious and costly. This could pose an important issue for businesses with limited funds, causing it to be hard for them to set up proper safety protocols (Taylor, et al., 2013; Kumar, et al., 2016). Human error leads to basic problems with standardized safety protocols in Cloud systems. Despite advances in technology, humans remain a vital element of safety measures, and human errors can introduce shortcomings (Probst, et al., 2010; Kaspersky daily, 2023). In conclusion, in the modern digital age, everything is becoming more difficult. This amount of detail makes it difficult for business entities to set up and oversee security solutions. With a lot to keep track of, it can be challenging to keep these security measures operating properly. Dealing with and maintaining the health of these complex computer systems requires an enormous amount of effort in order to remain ahead of emerging issues and keep things secure (Weill & Ross, 2004; Amirani, 2020).

3.1.2 Benefits of implementing standardized security controls

Standardized security measures are ever more crucial in the changing world of computing in the cloud for companies wanting to secure sensitive information, meet with regulatory responsibilities, and achieve their business objectives. Standardized security standards offer an extensive and coordinated method for protecting the cloud while reducing the chance of data breaches, unconstitutional access, and other security

concerns (Mather, et al., 2009). As a result, by getting data and maintaining compliance with legal and regulatory requirements, uniform security measures render it easier to comply with data protection laws like the GDPR (Walters & Novak, 2021). Furthermore, consistent security rules reduce the burden of IT employees by simplifying security employment opportunities, tasks, and operations. They can help businesses in lowering the monetary effects of security breaches, thus reducing the impact of incidents of security and operating costs (Boudreaux, et al., 2020). Finally, standardized security control solutions demonstrate an organization's ongoing dedication to data safety, trust, and reputation amongst consumers and business partners (Merkow, 2022).

3.2 Incident Response and Monitoring

3.2.1 Importance of effective incident management and monitoring

Regarding incident management and monitoring, a cloud-based environment presents a distinctive array of challenges as well as opportunities. As cloud services become increasingly utilized, organizations face a more diversified threat landscape and higher cybersecurity concerns. Furthermore, as to the dispersed nature of cloud infrastructure, an integrated Prompt learning and response to problems is critical for mitigating their impact on company activities. Effective incident management procedures help businesses in swiftly detecting threats, setting priorities, and dealing with problems, reducing disruption length and the potential for widespread harm. According to Gartner (2022), “organizations that implement effective incident management practices can reduce downtime by up to 50% and minimize the financial impact of incidents by up to 80%”. Cloud infrastructures are continually being targeted by cyberattacks, demanding sophisticated incident monitoring and response capabilities. Organizations can swiftly identify and react to security breaches by continuously monitoring cloud systems and applications for deviations and anomalies, protecting vital information, and avoiding financial losses (Lord, 2022).

Moreover, incident monitoring offers businesses with valuable insights into the health and effectiveness of their cloud infrastructure. Organizations can prevent system breakdowns while maintaining top performance by proactively tracking data and identifying possible issues and roadblocks, ensuring perfect business operations (IEEE, 2021). The clients, both internal and external, depend on businesses for protection of their data and offer trustworthy offerings. Effective incident management demonstrates the company's dedication to protection and trustworthiness, which promotes customer trust and loyalty (ISACA, 2021).

Finally, maintaining client satisfaction and efficiency necessitates minimizing interruptions, delays, and outages. Effective incident management systems enable companies to resolve issues promptly and efficiently, lowering disruption time and enhancing uptime (Maayan, 2021).

3.2.2 Critical factors that contribute to robust response and monitoring alignment

Evaluating the success of efforts to establish a successful response and monitoring alignment are both essential for ensuring continuous improvement and the general well-being of the IT environment. Key Performance Indicators (KPIs) provide an invaluable structure for analyzing performance and discovering potential areas of improvement and further refinement. The major key performance indicator (KPI) is the percent of downtime avoided. Downtime occurs when a system or application is not available for use by end users. Monitoring the total amount of downtime avoided shows how successfully the IT system and infrastructure protect against service disruptions. This KPI is determined by dividing total downtime by total available time, and the result is shown as a percentage (Kim, et al., 2018; Snyder, et al., 2010). The next key performance indicator (KPI) is system stability. This KPI effectively gauges the system's ability to maintain consistent performance while preventing unforeseen errors or breakdowns. Measuring system stability assists in identifying possible problems that might cause downtime or poor performance (Beyer, et al., 2016; Johnson, 2014). Performance and reliability are further important performance indicators for assessing the alignment of response and monitoring. The speed and effectiveness with which requests and services are handled and offered determines how well a system functions. The ability to maintain the confidentiality of information and regularity of performance is referred to as reliability. Typical performance and reliability metrics include response times that are defined as the length of time it takes a system to respond to a request. The word "throughput" refers to the rate at which data may be processed by a system. Rates of error are calculated as the frequency with which errors or exception happen, and, data corruption rates, often known as the frequency with which data corruption occurs (Allspaw & Robbins, 2010; Limoncelli, et al., 2014).

Finally, Customer Satisfaction is another key performance indicator (KPI) for handling incidents and monitoring. This KPI primarily pertains to the level of satisfaction that users have with a system's performance and reliability. The KPI is essential because it reflects end-user perceptions of efficacy and reliability, which have a direct impact on total satisfaction. Customer satisfaction consists of every aspect of the user experience, and most importantly, it includes the fact that they feel supported and get a prompt response in case of complaints or problems (Hayes, 2008). By measuring these KPIs, one may acquire some useful insights into the overall health and performance of IT infrastructure. The collected data may be used to identify areas or room for improvements, prioritize resource allocation, and make qualified and data-based decisions to increase the overall monitoring and incident response capabilities of an organization.

3.3 Resource Scalability and Cost Optimization

3.3.1 Resource Scalability Challenges

Efficient resource management in cloud computing is a crucial problem in many organizations; hence, it is important for organizations to address these challenges in an efficient and effective manner.

The most significant obstacle is financial. Uncontrolled resource scaling can lead to increased expenses, therefore good spending management is vital. Consequently, building a price-control system and using technologies can help with cost management and optimization. Furthermore, handling resources leads to both over- and under-provisioning. Over provisioning contributes to an organization's expenditures, whereas under provisioning causes application latency (Erl & Mahmood, 2013; Goodarzy, et al., 2020; Osypanka & Nawrocki, 2022). Following this, resource scaling could restrict performance, reducing both responsiveness and user experience. In simple terms, while operating big applications to increase the availability of cloud resources, scalability may have an impact on the performance of virtual machines (Atchison, 2016; Leite, et al., 2019). Another difficulty is the fact that many companies do not appropriately manage their resources, resulting in waste of resources and inadequate utilization. Furthermore, expecting the need for resources may be problematic for businesses, resulting in over- or under-provisioning (Travieso-Gonzalez, et al., 2023).

Speaking of obstacles, another problem with growing resources is maintaining compliance with regulations in the sector. Establishing right and correct governance standards and verifying that business activities adhere to regulatory requirements can be tough at times (Buyya, et al., 2013). Last but not least, a lack of expertise is another impediment to resource scaling. It is difficult to adequately involve a subject when everyone on the team is unfamiliar with it. Cloud resources require suitable monitoring, and an absence of knowledge may result in insufficient monitoring settings, leading to additional issues (Brown, 2023).

3.3.2 Cost Optimization Strategies

“Cost Management or Optimization of cloud governance focuses on establishing budgets, monitoring cost allocation patterns, and implementing controls to improve cloud spending behaviours across the IT portfolio” (Azure, 2023). As per a report by Deloitte, on an average, organizations save 14% just by moving to Cloud (Deloitte Business Consulting, S.A, 2021). This statistic shows us the importance of cost optimization and why it is of high advantage for companies to implement successful best practices and strategies. Focusing on efficient use of Cloud not only brings security advantages, but also tangible financial benefits. Organizations need to be prepared to profit from this opportunity. Cloud computing cost management is a difficult task. Gartner Research made a framework accessible that explained how to help enterprises. According to this guiding framework, companies must learn how to create budget expectations and forecast or anticipate. They must then have continual access to information about how much clients spend on each program, project, and application. Following this, tracking is set up, businesses must search for methods to reduce their expenses. Expenses can be reduced by using the enhanced capacity to spot deviations and drive remedial efforts. Organizations can gain scalability by automation of their methods for making decisions. To plan, manage, and maximize the use of cloud computing, organizations must develop an assortment of competencies based on this guideline framework. The framework highlights standards of excellence in each of the included components and is relevant regardless of the organization's cloud deployment status. Figure 11 illustrates a number of substitutes for cloud cost management and optimization. It is split into five major sections: Plan, Track, Reduce, Optimize, and Evolve (Gartner Research, 2020; Annis, 2023; Khan, 2020).

3.4 Employee Training and Security Awareness

3.4.1 Significance of security training programs

Security in an organization is not exclusively an IT matter to be handled independently by the IT team. It encompasses everyone with the organization, irrespective of the roles and positions, and employees play a crucial part. Awareness and Training programs for the employees are essential in order to ensure employee engagement, behaviour change, compliance, incident prevention and response, reputation protection, and trust building (Cybellium Ltd, 2023). Employee involvement is boosted by safety awareness activities, which develop an awareness of responsibility and involvement in solid security procedures (Neal & Griffin, 2006). In addition, by addressing psychological concerns and building a culture of high security understanding, it is necessary to make sure that outstanding security training plays a crucial role in encouraging appealing behavioural changes among employees (Ajzen, 1991). Training programs are indispensable for ensuring compliance as they educate employees on regulation and legal requirements, as well as the significance of keeping up to established security standards (Sherif & Sherif, 1964). Plus, security training provides employees with the information and skills required to evaluate and respond to emerging security hazards, which plays a significant role in both incident prevention and successful response (Anderson & Bushman, 2002). The training programs serve protect an organization's image by lowering the likelihood of security breaches and handling the associated negative press (Fombrun, 1996). Finally, security training and awareness fosters faith among stakeholders by demonstrating the company's commitment to protecting both employee and customer or client data, thereby enhancing trust in internal processes (Mayer, et al., 1995). Furthermore, according to a survey conducted by IBM Security, 46% of organizations consider employee training and security awareness as the most common and significant investment (IBM Security, 2023).

3.4.2 Roadblocks to implementing security trainings and raising awareness

In accordance with a survey carried out by Verizon, organizations state that the biggest obstacles in implementing security training and increasing employee awareness include lack of budget (28%), lack of time (35%), lack of management support (17%), lack of employee buy-in (11%) and lack of training resources (11%) (Verizon, 2023). Moreover, these findings are consistent with the findings of, yet another survey conducted by PwC in collaboration with ISACA (Information Systems Audit and Control Association, 2022).

3.4.3 Cultivating a security-aware culture

Although adopting security training and awareness programs provides hurdles and constraints, companies may use some effective methods to get around these obstacles and develop a security-conscious organizational culture in the IT and cloud environments. The first and most critical stage in creating a security-aware culture is to obtain the approval and participation of the organization's management; without their support, the laws and regulations will remain unread and ineffectual. If upper management considers security and security awareness as a serious topic, it will naturally propagate across the organization and contribute to the development of an improved security awareness culture (Gardner & Thomas, 2014; MacKay, 2023). Another way to enhance security awareness is to commence from the beginning. It is needed that the idea of security and related issues be introduced from the very beginning of an employee's life cycle, namely during the period of onboarding. This will not only assist in contributing to the organization’s security, but it will also emphasize how pertinent the subject is to the new employee and, eventually, the entire organization (Executech, 2022; Winkler, 2022). Besides, given today's fast changing cybersecurity and cloud landscapes, organizations need to go beyond typical yearly or biannual security training courses to successfully tackle new vulnerabilities. A more frequent training tempo is necessary, and quarterly seminars or sessions or monthly micro-trainings have shown to be successful solutions for many organizations (Executech, 2022; Harkut & Kasat, 2023). Finally, effective exchange of information is critical for ensuring organizational security. Transparent and open communication channels enable the swift sharing of information with regard to dangers, weaknesses, and incidents, which is key to preventing and responding to security breaches (Spellman, 2018; Cavusoglu, Cavusoglu, & Goldman, 2014).

3.4.4 Measuring training and awareness effectiveness

"Key Performance Indicator (KPI) is a business metric that measures the performance and progress of a business against its key objective. The purpose of using KPIs is to help businesses evaluate success at reaching specific targets." (Oberlo, 2023)

The primary key performance indicator (KPI) for evaluating the achievement of organizational security training programs is the successful completion rate of security awareness training. This indicator represents the percentage of employees who have successfully completed security awareness training. A high rate of completion acts as evidence of active employee participation in the learning process, implying a possibility that they will proactively shield themselves and the business from potential risks (Majewski, 2022).

A further significant KPI is the result of phishing simulations, which defines the percentage of employees who click on phishing links or attachments in simulated IT phishing emails. In this kind of situation, a lower click rate is appealing since it corresponds with achieving the KPI and demonstrates a high level of resilience to phishing attacks (Jampen, et al., 2020). Additionally, the level of security incident reporting rate is a key performance indicator (KPI) that measures the amount of security issues reported to the organization's IT or security teams. A bigger reporting rate indicates that employees are aware of what is going on and appreciate the need of swiftly reporting such instances (Arctic Wolf, 2023). Lastly, simply implementing a training program is not enough; so, a KPI in the form of a security knowledge evaluation score is sought. This score is the median score on a security knowledge evaluation, having an elevated average indicating that employees possess an in-depth understanding and grasp of security best practices (Chapple, et al., 2021).

4 RESEARCH METHODOLOGY

A qualitative research design will be used to respond to the questions, achieve the study's objectives, and fill research gaps. The qualitative design technique is an ideal fit for the study's sensitive and difficult topic, requiring high level of precision, dependability, and user satisfaction. A qualitative research study will create openness through enabling respondents to elaborate on what they have to say and better understand what they want and need in order to overcome gaps in areas related to security and compliance in a business's cloud and hybrid settings. The evaluation of content will be the analytical method applied. Interviews will be conducted to collect data, which will then be thematically examined, recorded, and transcribed. Qualitative research designs typically depend on actual experiences of individuals and done in natural settings (Marshall & Roassman, 2016). The secondary data of the research comes from journal papers, books, websites, and other online sources, while the primary information is obtained through interviews. Qualitative research is analytical in nature and is most effective when a particular issue or gap has not yet been addressed by a specific group of people, or if the subject matter is just emerging (Morse, 1991 in Creswell, 2002). The qualitative analysis will be performed with purposive sample. The material in the sources is structured in a systematic way according to the topics of the sub-sections. Furthermore, semi-structured interviews will be conducted based on the literature review, giving an elevated level of comparison (Creswell, 2002). Appendix 1 comprises of interview guide intended for the purpose of this paper. The interviews were recorded with prior permission of the interviewees for the purpose of transcription compliant with GDPR. This is also essential and advantageous when conducting a more in-depth review of the interviews (Collis & Husset, 2013; Bryman & Bell, 2015).

5 DISCUSSION BETWEEN FINDINGS AND LITERATURE REVIEW

The dissertation's literature review outlines the primary problems that organizations face when implementing standardized security controls (Rob S., 2023; Taylor et al., 2013; Kumar et al., 2016; Probst et al., 2010; Kaspersky Daily, 2023; Weill & Ross, 2004; Amirani, 2020). The participants in the interviews validated these challenges, highlighting: firstly, a lack of awareness regarding security risks (R1; R2; R3); secondly, resource constraints (R1; R2; R4; R6; R7; R9); thirdly, human errors (R3; R4; R5; R7; R8; R9); and finally, the complexity of modern IT systems (R2; R3; R5; R6; R7; R9; R10). Furthermore, the interviews revealed new findings about challenges that were not covered in the literature review, such as the importance of top management and stakeholder support and collaboration (R6; R10), raising employee awareness (R7; R10), and proper planning (R3; R8).

Furthermore, the goal was to understand the primary benefits of applying traditional security procedures. According to the literature review, the results include better security posture, optimal data privacy and

compliance, higher efficiency and cost reduction, and improved trust and reputation (Mather et al., 2009; Walters & Novak, 2021; Boudreaux et al., 2020; Merkow, 2022). These findings are consistent with the viewpoints of the respondents. At the outset, 100% of respondents agreed that implementing standardized security measures greatly improve the company's security posture (R1; R2; R3; R4; R5; R6; R7; R8; R9; R10). Furthermore, 8 out of 10 respondents agree that trust and reputation can be improved (R1, R2, R3, R4, R7, R8, R9, and R10). The empirical evidence backs up the notion that higher efficiency and cost savings are beneficial, as respondents concur (R1; R2; R3; R5; R8; R9). Finally, 30% of respondents agreed on improving data privacy and compliance (R5; R6; R8). Among the key performance indicators for successful response and monitoring alignment highlighted in the literature review (Kim, et al., 2018; Snyder, et al., 2010; Beyer, et al., 2016; Johnson, 2014; Allspaw & Robbins, 2010; Limoncelli, et al., 2014; Hayes, 2008), the respondents aligned with only two: firstly, the percentage of downtime avoided (R1; R2; R3; R4; R6; R7; R9; R10), and secondly, the system stability (R1; R2; R4; R5; R10). In particular, some important conclusions from the literature review that were not represented in the interviews are linked to performance, reliability, and customer satisfaction. In contrast, several empirical results that were lacking from the literature review included incidence rate (R1; R3; R5; R7; R8), reaction time (R5; R6; R7; R10), and successful closure of internal and external audits. Important scalability challenges in a cloud environment, according to the results of the literature review, include cost management, performance challenges, inadequate resource provisioning, compliance and governance, and a lack of expertise (Erl & Mahmood, 2013; Goodarzy, et al., 2020; Osypanka & Nawrocki, 2022; Atchison, 2016; Leite, et al., 2019; Travieso-Gonzalez, et al., 2023; Buyya, et al., 2013; Brown, 2023). The aforementioned challenges are consistent with the perspectives of interviewees in the actual world (R1; R2; R3; R4; R5; R6; R7; R8; R9; R10). The interview findings also highlight other problems associated with resource scalability, especially forecasting (R3). In the midst of a difficulty, effective remedies are required. The literature review proposes a framework for controlling and improving cloud expenses that includes practical tactics such as Plan, Track, Reduce, Optimize, and Evolve (Azure, 2023; Deloitte Business Consulting, S.A, 2021; Gartner Research, 2020; Annis, 2023; Khan, 2020). Undoubtedly, all respondents agree with this structure and have helped define particular procedures or approaches for each component (R1; R2; R3; R4; R5; R6; R7; R8; R9; R10).

Finally, the literature review examines security training programs, outlining the problems, solutions, and critical aspects found while implementing staff training efforts.

Beginning with all of the obstacles outlined in the literature review (Information Systems Audit and Control Association, 2022), the majority have been substantiated by the respondents: firstly, a lack of time (R1; R2; R4; R8); secondly, insufficient budget (R2; R5; R6; R8; R9); thirdly, inadequate management support (R3; R4; R5; R6; R7; R9; R10); fourthly, lack of employee buy-in (R1; R2; R3; R4; R5; R6; R7; R9; R10); and finally, lack of resources (R2; R7; R8). A fresh discovery about challenges, which was not expressly discussed in the literature review, is lack of understanding (R10). In addition, tackling the solutions, the vast majority of challenges established in the literature review (Gardner & Thomas, 2014; MacKay, 2023; Executech, 2022; Winkler, 2022; Executech, 2022; Harkut & Kasat, 2023; Spellman, 2018; Cavusoglu, Cavusoglu, & Goldman, 2014) have been clearly stated by the respondents: involving management (R2; R4; R5; R8; R9; R10), advocating for best practices (R9), integrating security from day one (R3; R4; R7), conducting regular trainings. Respondents did not expressly address the inclusion of various concepts to promote awareness. Furthermore, the interview findings stress on change management (R3), which is not expressly addressed in the literature review.

Ultimately, in the discussion of key performance indicators (KPIs), the literature review highlights four core criteria, the majority of which were also stated by interviewees. These include the completion rate of security awareness training (R4; R6; R8; R10), the outcomes of phishing simulation (R1; R2; R3; R5; R6; R7; R8; R9; R10), the rate of security incident reporting (R3; R4; R6; R9), and the security knowledge evaluation score. The respondents also mention click rate (R1; R2; R7; R8; R10) and time spent on training (R9) as additional KPIs to consider while assessing the success of security training in a business.

6 SUMMARY OF PRESENTATION OF FINDINGS

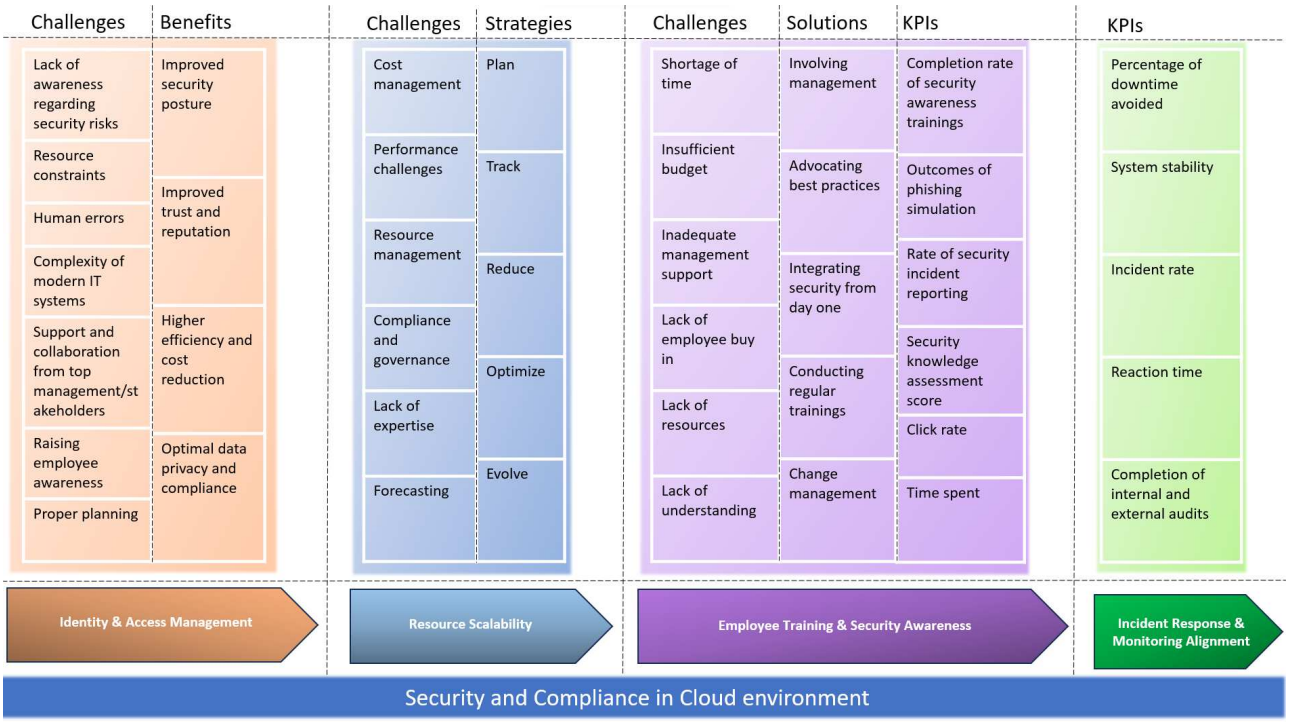
Although the cloud has enormous potential, its implementation requires negotiating a difficult security and compliance landscape. The methodology explained in this chapter is based on interviews with professionals and aims to prepare businesses to better understand the areas.

The focus kicks off with Identity and Access Management, where the key is to strike a balance between granular access limits, user ease, and successfully maintaining privileges using role-based accesses. Implementing this provides organizations with benefits such as great data protection, compliance, and reduced breach risk. The framework aims to provide the possible challenges and benefits in cloud.

Next, we talk about resource scalability. The issue is to maintain strong security despite unforeseeable resource variations while assuring consistent configurations across different scenarios. The section of the framework is aimed at explaining the challenges and practical strategies to successfully scale up or scale down resources in an organization.

Furthermore, the framework covers employee education and security awareness. The goal is to keep employees informed about emerging hazards, foster an awareness culture, and evaluate training performance. Overcoming these hurdles results in lower phishing danger, improved data cleanliness, and proactive reporting of suspicious activities. Ongoing training, simulating phishing attacks, and promoting secure behaviour are critical implementation components.

Lastly, it is equally important to develop a clear incident response strategy. Constant cloud monitoring of resources and computerized security incident management are critical for swift identification and reaction, resulting in less damage, faster resolution times, and a stronger overall security posture. In this regard, the framework explains the main critical factors which are stepping stones for an organization to succeed in the area. The below figure is a visual roadmap that guides businesses through possible risks, mitigation techniques and critical factors for building a strong cloud security and compliance architecture. Security and compliance are ongoing journeys. Embracing this framework as a flexible foundation may evolve as your cloud environment expands.



7 CONCLUSION

As a conclusion a right balance model between compliance and governance at the one hand and openness and degrees of freedom at the other hand, to secure the security and fluent delivery of smart city processes and infrastrcture operations in modern cloud environments.

The constantly changing characteristics of cloud computing demands an attentive approach to security and compliance. The characteristics of cloud computing systems must have a strategy that tackles multiple elements, as mentioned in the introduction of this paper. This encompasses identity and access management, incident response and monitoring, resource scalability, cost optimization, and efficient employee security training. Identity and Access Management (IAM) is essential for enhancing security and compliance in the cloud while establishing the groundwork for managing access to sensitive data. The challenging task of

embracing compatible safety measures in IAM has associated advantages, such as lowered unauthorized access risks and enhanced adherence, which emphasize the need of overcoming the hurdles discussed in the paper. Successful incident response and tracking strengthen the cloud's security posture, pointing out the necessity of proactive oversight in mitigating potential threats. Resource scalability and cost optimization are crucial variables, requiring an accurate compromise between satisfying altering workload requirements while retaining ideal resource allocation. Employee training and awareness programs handle the role of the human aspect of security, and this is imperative for fostering a security-focused mindset.

Combating obstacles to implementation needs to be a team effort to implement security standards into actual actionable processes and procedures. Assessing the efficacy of these initiatives exposes significant details about an organization's security as well as opportunities for advancement. In short, an integrated and comprehensive approach to IAM, incident response, resource management, and knowledge among employees must be implemented for organizations to navigate the complex environment of the cloud securely and successfully.

Following extensive research and 10 interviews with professionals, it emerged that security and compliance in an organization should be of the utmost importance, not just for the long-term advantages it provides, but also for building confidence and reputation in the minds of employees and other internal and external stakeholders. Additionally, it is strongly recommended to start using actual solutions and tools, such as organizing administrator rights on a global level or central level and allocating them to the right people. Furthermore, linking business objectives with real-time threat identification and lightning-fast response times is critical. Also, provided the value of resource scalability and cost optimization, systems such as Hydra, Nerdio Manager for AVD, ControlUp Workspace, among others can be implemented to tackle scalability issues and meet the demands of increasing workloads. Finally, no accomplishment can be achieved without the active participation of employees; thus, employee education and awareness of security related topics are fundamental.

In essence of this paper, an in-depth strategy to cloud security and compliance involves technological advances controls, proactive incident management, cautious spending, and a cyber-conscious mentality. To stay ahead of the curve, organizations have to handle barriers, adopt best practices, and change their strategy on a regular basis. Businesses are able to fully capitalize on the benefits of the cloud as long as they undertake an entire and seamless approach that protects their data, infrastructure, and reputation.

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Small-scale Production Sites as Part of Urban Resilience Infrastructure: The Intersections of Urban Planning and the Fab City

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1 ABSTRACT

Research in the wake of recent international crises points to the potential of urban production, particularly small-scale, accessible, digital production sites such as Fab Labs and makerspaces, to strengthen cities' resilience by contributing to faster response times in the development and creation of innovative products and to knowledge-sharing and skills development for local communities (HILDEBRANDT et al. 2022). This has been recognized by a growing group of cities who have joined the Fab City Global Initiative, which now includes 52 members (FAB CITY FOUNDATION). The Initiative envisions a future of almost completely local and circular production, as part of a globally connected and mutually collaborative distributed production network (DIEZ 2016). At the same time, cities are facing an overall long-term trend in which productive uses are disappearing from the inner-city and being pushed to the peripheries (BENKE 2021; DE BOECK/RYCKEWAERT 2020; HATUKA/BEN-JOSEPH 2022; JURASCHEK 2022; NOVY 2022). This is continuing despite – and, in some cases, even driven by – cities' strategies to encourage sustainable urban development and the adoption of guiding principles for urban planning such as mixed-use zoning, the 15-minute City, etc. (BRANDT et al. 2018; LIBBE/WAGNER-ENDRES 2019; RYCKEWAERT et al 2021; SCHROCK/WOLF-POWERS 2019).

The current number and scale of small, accessible, digital production sites like Fab Labs is still inadequate to meet the needs of the Fab City vision and to fulfill the potential for significant impact on cities' resilience (HILDEBRANDT et al. 2022). Expansion of these sites is made more difficult by the high competition with other uses for exactly the type of central and accessible spaces that small production sites need (DE BOECK/RYCKEWAERT 2020; LIBBE/WAGNER-ENDRES 2019). A product of the project "Fab City: Decentral, digital production for value creation" (funded by dtec.bw, NextGenerationEU), this paper links these challenges with the role of urban planning in the integration of small production sites in the existing urban fabric. Drawing on the literature and discourse on urban production, as well as interviews and observations of OpenLabs set up in Hamburg in the Fab City project and case reports on other small digital production sites, we elaborate a set of factors of urban integration for these sites. We then propose key areas in which further research is needed in order to develop or adapt planning instruments and policies to support the incorporation of these forms of production as part of the resilience infrastructure of urban neighborhoods.

Keywords: Fab Lab, Fab City, planning, urban production, urban resilience

2 INTRODUCTION

The past years have brought with them several crisis events which have demonstrated the fragility of global logistics networks and have highlighted the precarious nature of cities' reliance on them. These range from shipping accidents and escalating violence around the Suez Canal, to the Russian war in Ukraine, to the Covid-19 pandemic. In all cases, wide-ranging impacts on trade have been observed and have had repercussions for cities and their residents as demand for certain goods and materials have changed at the same time that availability and costs have fluctuated. The discourse on urban resilience emphasizes the need for cities to strategically consider these and other hazards and to develop new infrastrutures, policies, networks, and transparent processes to respond to them (see e.g. MEEROW et al 2016; SHAMSUDDIN 2020; WARDEKKER 2021).

Rooted in an international network of Fab Labs which grew out of a project at MIT's Center for Bits and Atoms, the Fab City Global Initiative was founded with the goal of enlisting cities which pledge to work towards a transformation of their production and consumption systems "from 'Products In Trash Out' (PITO) to 'Data In Data Out' (DITO)" (DIEZ 2016; DIEZ et al 2019). Reslience is explicitly mentioned by

the Fab City Initiative as a core goal for the Fab Cities, emphasizing the contribution of a strong focus on local business, workforce, and supply chain development towards combatting urban challenges such as climate change, impacts of globalization, etc. (DIEZ 2018). Barcelona became the first member in 2014 and is now joined by 37 other cities, eleven regions, two countries, and one island (FAB CITY FOUNDATION). Concrete commitments and strategies differ, however the members pledge to work towards the production of "(almost) all the energy, food and products they consume, to deploy circular economy strategies for the relocalisation of production, and the technological empowerment of citizens" by 2054 (FAB CITY GLOBAL INITIATIVE). Hamburg became the first German city in the initiative in 2019 (FAB CITY FOUNDATION; BEHÖRDE FÜR WIRTSCHAFT UND INNOVATION).

2.1 Small-scale, accessible, digital production

Fab Labs and makerspaces represent certain types of small-scale, accessible, digital fabrication sites, which have been recognized as a new form of production infrastructure in cities (MEYER/ESCH 2023). When discussing this model of production, terms such as makerspace, Fab Lab, hackerspace, repair café, etc. are used rather interchangeably. These are community workshops, open to the public (in some cases in exchange for a membership or usage fee), and providing access to digital production machinery such as 3D printers or CNC cutters, as well as some traditional tools like drills or sewing machines. They share the mission of supporting people to make things, whether out of necessity, as an educational project, as a business or product protoype, or 'just for fun' (CENERE 2021; DIEZ 2012; TROXLER 2016). Thus, they are part of Fab City's envisioned distributed production network that cycles materials and products locally and regionally, while design data, skills, and knowledge are exchanged both locally and globally.The Fab City concept forsees the implementation of Fab Labs as physical spaces in urban neighborhoods which house citizens, business, research, educational efforts, etc. for the purpose of "social fabrication" as an integral part of the larger "fabrication ecosystem" (DIEZ 2012; DIEZ 2016).

Increasingly, these types of production sites are being discussed as potential contributors to urban resilience, whether in terms of sustainability, supply chain localization and responsiveness, community building, etc., but have not reached the scale and capacity needed to attain significant impacts (see e.g., HENNELLY et al. 2019; HILDEBRANDT et al. 2022; LÄPPLE 2016; MONACO/HERCE 2023; RUMPALA 2021; PEEK/STAM 2019). However, growth in the number and capacity of small-scale production sites in cities poses several challenges related to the physical, regulatory, and social frameworks within urban neighbourhoods (BENKE 2021; LIBBE/WAGNER-ENDRES 2019; SCHMITT et al. 2019; SCHONLAU et al. 2019; SCHREINER 2021).

This paper deals with these challenges at the intersection of urban planning and the integration of small-scale production. Our research has been enabled through the project "Fab City: Decentral, digital production for value creation" (funded by dtec.bw – Center for Digitalization and Technology of the German Federal Armed Forces, which is financed by the European Union – NextGenerationEU) under the leadership of the Helmut Schmidt University. Within this project, several OpenLabs have been established which house a range of productive approaches and focus on open source methods. Drawing on the literature and discourse on urban production, as well as interviews and observations of two OpenLabs in Hamburg and case reports on other small digital production sites, we propose a set of factors to describe the aspects of urban integration of these sites. We further explore the relevance of small-scale, accessible, digital production sites for urban resilience within Wardekker's (2021) framings of Resilience Planning and Resilient Community Development. We then propose key areas in which further research is needed in order to develop or adapt planning instruments and policies to support the incorporation of these forms of production as part of the resilience infrastructure of urban neighborhoods.

3 URBAN PRODUCTION AND RESILIENCE

The achievement of broad Fab City goals will require production transformations at many different scales, both inside and across urban/regional boundaries. Within cities, the type and scale of production varies from individual creative work to traditional crafts to agriculture to heavy industry. The formal definition of urban production is under debate in the literature, along two core questions. First, researchers set different boundaries according to which context is sufficiently urban and how that can be determined (HAUSLEITNER et al. 2022; JURASCHEK 2022; PIEGELER/SPARS 2021; SCHMITT et al. 2019).

Second, they disagree about whether production should be limited to physical items or should include knowledge and services (BRANDT et al. 2017; DE BOECK/RYCKEWAERT 2020; GÄRTNER/SCHEPELMANN 2020; LIBBE/WAGNER-ENDRES 2019; PIEGELER/SPARS 2021; SCHMITT et al. 2019). We adopt the material understanding of urban production, as this best reflects the function of small-scale, accessible production sites as it relates to urban planning. That is, the fact that physical products are created at these sites, though in many cases alongside or in addition to knowledge production, separates them functionally from purely non-material productive uses in terms of regulation and management within urban planning.

While there are many theoretical approaches underlying the concept of urban resilience, for the purposes of this paper, we apply the definition suggested by Meerow et al. (2016, pp. 39):

"the ability of an urban system – and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales – to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity."

This definition highlights the interconnected and multi-scalar set of systems that are involved in considerations of urban resilience. In the context of urban production, this differentiation is significant, as scales, systems, and communities of production have changed over time. Especially in the context of the Fab City concept, the networks of production differ substantially from the status quo in terms of spatial scale. General discussions of urban production often link it to urban resilience in connection with sustainability: via socio-economic concerns such as retention of certain industries or workforce development, or within Circular Economy debates (see e.g. COSKUN et al. 2022; HAUSLEITNER et al. 2022; LIEDTKE/BÜTTGEN 2021; PEEK/STAM 2019; RAPPAPORT 2020; SCHONLAU et al. 2019). Local manufacturing and small-scale production, in particular, are emphasized as key actors supporting urban resilience through their production activities and knowledge generation but also as endangered members of the urban fabric, who are at risk from economic pressures and urban development changes (see e.g. BRANDT et al. 2018; HILDEBRANDT et al. 2022; MARTIN/GRODACH 2023; SCHROCK/WOLF-POWERS 2019).

In considering these conflicting positionings of urban production, Wardekker's (2021) additional framings of resilience are helpful, contrasting the perspectives of the systems approach with that of a community focus and combining this with the aspects of "equilibrium" versus "evolution." This results in four framings: Urban Shock-Proofing (systems + equilibrium), Resilience Planning (systems + evolution), Community Disaster Resilience (communities + equilibrium), and Resilient Community Development (communities + evolution) (WARDEKKER 2021). While discussions of urban production touch on all of these framings in different respects, the equilibrium perspective is more present, e.g. responses to disasters and shocks or reindustrialisation. The Fab City Initiative's goals imply, however, a fundamental disruption of the existing production and consumption systems which removes (almost) all extra- and interregional material and product flows and reimagines the role of citizens as prosumers (DIEZ 2012; UNTERFRAUENER et al. 2017).

This relies on a significant re-alignment towards digitally-supported production methods and a new, broader conceptualization of the actors in the production system, and it confronts the evolution perspective of resilience. One line of research into the Fab City and the Maker Movement can be grouped around this shift in the development of communities and networks of production (e.g. CENERE 2021; GARNIER/CAPDEVILA 2023; UNTERFRAUENER et al. 2017). The corresponding line of research takes a systems focus on what kinds of specific (co-)production infrastructure are demanded by a Fab City and how these can be envisioned in the urban space (e.g ELWAKIL et al. 2023; HENNELLY et al. 2019).

3.1 Urban planning and integration of production

We refer to the integration of urban production in terms of the implementation and embedding of a production site in a neighborhood in physical and social terms. Physically, urban integration includes land use and planning, local mobility, energy, digital, and other infrastructures, and materials. Socially, urban integration describes the bidirectional relationships of local, social, and economic structures and networks with the production site. It is similar to the concept of 'embeddedness' in some English-language studies (e.g. TSUI et al. 2021). Under the guiding principle of mixed-use planning adopted by the urban planning profession over the past 30 years (BBSR 2017), cities are attempting to reverse the dis-integration of urban

spaces which happened as a result of the 20th Century planning philosophy of separation of uses and the implementation of strict land-use policies (RYCKEWAERT et al. 2021).

Detailed descriptions of the evolution of productive industry and manufacturing in cities historically can be found in the literature and from the Cities of Making project (e.g. CROXFORD et al. 2020; JURASCHEK 2022). The broad trend has seen the urban factories which arose as part of the inustrial revolution and traditional, local craft and manufacturing sites increasingly pushed to cities' peripheries by zoning and land-use regulations (DE BOECK/RYCKEWAERT 2020; HATUKA/BEN-JOSEPH 2022; JURASCHEK 2022). Despite this, studies show that industry and producers do prefer to locate in or near mixed-use areas with certain urban characteristics: for access to networks of other companies or producers in their field, better transportation infrastructure, better access to customers or for employees, etc. (BONNY 2021: GÄRTNER et al. 2021; HATUKA/BEN-JOSEPH 2022). Increasingly, the mutual benefits for industry and cities that stem from intentional cooperation around urban production are being recognized, as, for example, discussions of urban industrial symbiosis show (e.g. JURASCHEK 2022).

The movement towards mixed-use planning policy has been slow to yield measurable positive results for productive uses (BONNY 2021; PIEGELER/SPARS 2019). Mixed-use zones typically assign a certain percentage of area to different uses, however, in the German planning system, there is no specific usage category for production. Depending on the nature of the production, it might fall under commercial or industrial use categories. This means it is not possible to assign a certain amount of production to a mixed-use area, and that productive users then compete against other commerical or industrial users for these spaces (LIBBE/WAGNER-ENDRES 2019; SCHMITT et al. 2019). Frequently, formally exclusively industrially zoned areas are changed to mixed-use, but resulting development policy choices that prioritize higher profit residential and office uses lead to an overall decrease in the amount of space used for production (DE BOECK/RYCKEWAERT 2020; LIBBE/WAGNER-ENDRES 2019). Some describe this process as 'industrial gentrification,' in which productive uses experience the same spiral of rent and operational cost increases and eventual displacement as some poorer urban residents of newly fashionable neighborhoods (BRANDT et al. 2018; RYCKEWAERT et al. 2021; SCHROCK/WOLF-POWERS 2019).

Another issue limiting the expansion of production sites in mixed-use areas and their preservation in existing neighborhoods are conflicts that arise from noise, emissions, traffic generation, or other potential nuisances for the community. These nuisances are regulated within local zoning codes according to specific metrics, such as maximum decibel levels during daytime and nighttime. In existing neighborhoods, so-called 'NIMBY' (Not In My Backyard) movements can arise and drive an existing production site away or even prevent a productive use from entering the area through legal means (GÄRTNER/STEGMANN 2015). Residential concerns are usually prioritized for protection in these cases, which leads to an increased chance of displacment for production (BENKE 2021; SCHREINER 2021). There is a general lack of awareness of benefits or of active local proponents of production and, especially close to residential areas, a tendency of citizens and planners to fear potential conflicts (LIBBE/WAGNER-ENDRES 2019; SCHONLAU et al. 2019).

Small-scale, digital, accessible production sites such as Fab Labs and Makerspaces have been proposed as good practice examples of new urban production which can contribute to increased awareness among citizens and planners (LÄPPLE 2016). The digital production tools and methods they apply are less likely to cause a nuisance to the local community directly, although not all potential problems can be solved with technology. For example, traffic at the production site might still be a issue (BENKE 2021). Labs need to be consciously and conspicuously integrated into neighborhoods, though, in order to activate and engage the local community: residents, as well as building owners, local businesses, and social networks (SCHONLAU et al. 2019).

Still, not all labs or production sites have the same demands, and their thematic or technical focus impacts the extent to which physical, economic, and/or social aspects or networks are prioritized. Lange et al.'s (2016) survey of open workshops in Germany shows, for example, a higher level of local engagement in repair workshops compared to the city or even region-wide user-shed found in workshops focusing on new production. Further typologies of small-scale, accessible production sites also distiguish between their relationship to products and to community engagement. Hennelly et al. (2019) group several makerspaces in types along a spectrum from educational focus to operational productive focus and highlight tradeoffs, e.g.

agility or scale, that come with different foci operationally and in local networks. Capdevila (2017) differentiates between innovation spaces with specific topic specialization and without, 'dirty' vs 'clean' productive activity, and with "activist" identities or without them.

The type of site can also be determined by the materials in use and needed connections to material flows, with associated consequences for the type of space and location of the site that are typically observed (ELWAKIL et al. 2023). All of these studies touch upon the differences in the level of local community interaction and types of actors engaged that their different types imply. Most informative from a physical planning perspective, Elwakil et al. describe in greater detail the spatial context and built environment of their five types of makerspaces and mention important siting considerations such as transportation network access, connections to historical craft communities, or nexus points of different land uses. Table 1 summarizes Elwakil et al.'s types of makerspaces.

Type	**Building type/use**	**Highly-frequented places?**	**Land use**	**Population density**	**Further points**	
Reuse Makerspace	Stores, shops, markets	Yes	Residential-commercial nexus	Higher	Public transit hubs close-by	
Repair Makerspace	Public or non-profit spaces, also shops, garages, etc.	Yes	Residential-commercial nexus	Higher	High diversity depending on service orientation (bottom-up café model vs "private repairers")	
Craft Makerspace	Small shop/café	Yes	Residential-commercial nexus or commercial	Higher	Social and productive aspects combined; target general public	Connection to history of craftsmanship in the local area
	Larger workshop	No	Industrial	Lower	Need for larger tools or machines; target specialists	
Fabrication Makerspace	Sharing educational or university spaces	No	Institutional or Industrial	Lower	Open to public; Educational and training focus	
Distribution Makerspace	Larger warehouse or sharing waste management spaces	No	Industrial or industrial-commercial nexus	Lower	Roads and large vehicle access needed; collection, sorting, transfer of goods rather than production.	

Table 1: Summary of Elwakil et al. 's (2023) makerspace typologies. Own illustration.

Each of these studies also emphasize the hybridity of their proposed typologies. The sites they investigated have, for the most part, characteristics of multiple types and the categories remain fuzzy, with different researchers using different characteristics to distinguish between types.

These discussions about urban production and about open production sites identify several points of thematic relevance to urban planning and urban development. Typologies and case studies of production sites reveal the high level of diversity among urban production and producers. By synthesizing these aspects into a set of factors, we aim to develop insights into the overlap of planning concerns and collaborative local production which can help inform efforts to expand small-scale, digital production in urban neighborhoods.

4 METHODOLOGY

To develop the factors of urban integration of small-scale, accessible, digital production sites, we performed an analysis of reports and studies on the operation and implementation of these sites. We relied on a snowballing method to compile a core set of studies, beginning with publications of the Fab City movement and related project reports and building onto this with searches in Google Scholar combining key terms from the literature around urban production and urban development with 'Fab Lab' and 'makerspace.' Searches were conducted with both English and German terms. The citations within the resulting texts and the sources which cited them were considered for inclusion in the inventory. Texts were selected that described the implementation or operation of a small-scale production site at a physical location or that described studies

(surveys, interviews with staff or makers, etc.) of small-scale production sites at one or more locations. The key unifying element was the physical presence of the site as an operating productive use in a space dedicated to this purpose. Visioning or strategy processes and reports about the conceptual planning of potential future productive spaces or activities were not examined. Similarly, we excluded production activities held exclusively as part of temporary events (e.g. festivals) and mobile production units, as well as texts describing the development or protoyping of a single product or process rather than the site itself. Studies were also limited to those covering cases in urban planning contexts similar to Germany (Europe, UK, North America, Australia, etc.), excluding as well those that focused on informal settlements.

This search resulted in 21 texts, which underwent Qualitative Content Analysis (see, e.g. MAYRING 2000) using a combined deductive and inductive approach. The text included studies of German cases (5), European studies with single non-German cases or multiple cases (12), and international studies (4). Core themes of urban integration from the literature review of urban production and urban development discourses composed initial categories and sub-categories for coding. These categories were iteratively expanded as new topics arose out of the reviewed texts, and the coding of texts then validated again. The systematic analysis resulted in 70 initial factors, across seven thematic categories (space and location, planning instruments and structures, useage, infrastructures, networks and community, local economy, materials and waste). Two Fab City project OpenLabs, operational at dedicated sites in urban neighbourhoods in Hamburg, were also the subject of further first-hand observations. Both labs share a thematic focus on material circularity and development of circular business models:

- OpenLab_Textile, focusing on fabrics and clothing design and production, located in a former shop space in a commerical area along a pedestrianized street in the inner city.
- OpenLab_Plastic, focusing on production with recycled plastics, located in a building housing other productive uses in the inner periphery of the city and along a major road. The site is on the edge of an industrial area which borders areas with residential useage.

Drawing on insights gained through observations of the labs and interviews with lab management, the preliminary list of factors was synthesized into three types: operational factors (internal or management concerns), urban environmental factors (external, influencing the Labs but not significantly influenced by them), and integrative factors (bi-directional relationship to the labs). Factors related exclusively to operational concerns or management of labs or makerspaces were then excluded as they fall outside of the scope of urban integration. These constituted a large share of the preliminary list, as many studies discussed, for example, business models and interior design concerns of individual labs in detail.

5 FACTORS OF URBAN INTEGRATION

Table 2 presents the resulting list of 26 factors. They are divided into four thematic categories: built environment and physical space, local planning and useage, material and waste, and networks. These factors summarize the elements of urban integration discussed in case studies of productive makerspaces and labs across various contexts. In order to highlight the extent to which the production site has the potential to influence the factor, we further distingusísh between factors with exogenous and endogenous character.

The factors considered exogenous are those that the production site does not have the ability to influence directly and which, thus, act to some extent as determinants of the form and nature of the implementation and/or operation of the site. These are described in the reviewed cases often as criteria taken into account in siting and location choice by lab founders. The factors considered endogenous are those for which the research can already demonstrate potential for a bi-directional effect. This methodology does not reveal the character of the factors' impacts, whether positive or negative on the production site or the neighborhood. The elements that are more or less important for successful implementation differ according to the individual goals of lab founders or the operational framing of the production in terms of materials, target groups, etc. Although some insights can be drawn from the literature and local case studies, further research will be needed both to validate the factors in further cases and to elaborate the nature of their impacts.

Regarding the category of built environment and physical space, as observed in Hamburg and in the examined case studies, the production sites operate in existing buildings and neighborhoods at a scale too small to influence physical infrastructures. Within these limits of scale, though, highly visible presence of the site and open concepts of use of space (sharing) can have impacts on the use of space and the atmosphere of

the street in a localized manner (MATTIOLI 2021; SCHONEBOOM 2018). The examined reports also demonstrate that founders search for certain context characteristics for their production sites, such as an industrial past (e.g. CENERE 2021; JOHNS/HALL 2020) or proximity to certain user groups, such as youth or entrepreneurs (e.g. MATTIOLI 2021). While current studies show a more reactive relationship of small-scale production sites to other factors in this category, e.g. costs of or demand for space as a driver of location choices, research into industrial and social gentrification processes implies potential for endogeneity. This could include, for example, the production site driving a change in the perception of the socio-economic character of the neighborhood, whether indirectly or as part of a concious development process or investment (see, e.g. SCHROCK/WOLF-POWERS 2019).

Built environment and physical space		
	Factor	Description
Exogenous	Availability of space	Availability of appropriate space for a lab that is also free in the desired time period
	Centrality of the location in the neighbourhood or city	Proximity to the centre / 'core' of the neighbourhood or highly frequented locations
	Built context and history of the site	Existence of a certain historical character, building types, or identity of the neighbourhood or location, e.g. craft or industry/warehouse district
	Infrastructure for transportation and mobility; Accessibility	Existence and quality of access to mobility infrastructure and services in and around the location for passenger and freight transport
Endogenous	Cost of the space	The costs of renting the space and/or other costs associated with the use of the premises
	Demand for space	The level of demand for appropriate spaces in the neighbourhood, e.g. competition
	External impact/visibility of the location or rooms	The impression of the lab from the outside, e.g. the ability to recognize it (signage, visibility in the streetscape, etc.) and to understand it passively (looking through windows into the lab, information about offers, etc.)
	Options for space sharing	Possibility of using the space/rooms of other institutions or organizations for a lab project or providing space in the lab for other users/initiatives
	Socio-economic context of the site	Existence of a certain socio-economic character or identity of the neighbourhood or location, e.g. population age or wealth, social disadvantage, etc.
Local planning and usage		
	Factor	Description
Exogenous	Zoning policy at the site	The type of use foreseen for the site according to the local zoning plans, e.g. commercial area, mixed-use area, etc.
	Building use for the site and associated permitting	The type of usage approved for the building itself (e.g. office use, commercial use, warehouse, etc.) and any associated applications for a change of use or permitting processes
	Economic or business development	Existence or possible use of relevant city or private support programs (start-up or innovation promotion, personnel development, creative interim uses, etc.)
	Neighbourhood or community development	Existence of or possible participation in city-level or district-level strategies or social support programs
Endogenous	Visitor traffic	Planning for and effects of possible visitor flows to the lab on the neighbourhood, both in normal operation and during events (e.g. parking, traffic volume at certain times of day, etc.)
	Noise and air pollution	Experience with or recording of possible noise or air emissions from lab operations and their possible effects on the neighbourhood
	Relationships with neighbours	Interaction with neighbours (residents or businesses in the immediate vicinity) in the context of lab operations, in particular identification of other potential disruptive factors or conflicts that are relevant in the context of the use permit
Material and waste		
	Factor	Description
Exogenous	Waste disposal	Existence of special disposal options (e.g. recycling, waste separation) at the lab site or close by
Endogenous	Procurement and use	Availability and possible use of material from local/regional sources
	Re-use	Opportunities to re-use materials, e.g. local or regional networks or suppliers
Networks		
	Factor	Description
Exogenous	Production und other producers(location)	Presence of other Fab Labs/makerspaces, crafts, or further manufacturing in the neighbourhood or in close proximity to the lab
	Educational or research infrastructure (location)	Presence of schools, universities, universities of applied sciences or other educational institutions in the neighbourhood or in close proximity to the lab
	Cultural and social infrastructure (location)	Presence of social and cultural facilities, actors and initiatives in the neighbourhood or in close proximity to the lab
Endogenous	Production und other producers (interactions)	Interactions with other labs, makerspaces, craftspeople or similar producers in the neighbourhood or city
	Educational or research institutions (interactions)	Interactions with schools, educational institutions, research organizations in the neighbourhood or in the city
	Cultural and social institutions (interactions)	Interactions with social and cultural institutions in the neighbourhood or in the city
	Community outreach and lab offers	Development or adaptation of lab offers or communication about the type and scope of offers for specific target groups in the neighbourhood or city

Table 2: Factors of urban integration.

Factors of local planning and useage, central to this research, were generally mentioned less frequently in the reviewed texts than the other categories. The descriptions of space and buildings were much more detailed, and discussions of land use or permitting concerns were found in only a few instancecs (e.g. ARMONDI/DI VITA 2021; BUTZIN/MEYER 2020). The exogenous factors of zoning and use/permitting here seem to be handled as preconditions by operators of some production sites or, in one Hamburg case, were avoided through temporary exceptions. At the city level, economic development policies that also include opportunities for support for small-scale production and produers and social support or inclusion programs have been found to be an important contributor to success (ARMONDI/DI VITA 2021; SCHROCK/WOLF-POWERS 2019). Nuisance concerns and potential conflicts with other uses in the neighborhood were not as present in the case studies as the urban planning discourse would imply. The Hamburg OpenLabs did not yet experience any conflicts or complaints from their neighbors, despite the production of noticeable fumes and noise. The lab management mentioned their attempts to limit the use of loud or odor-producing machinery to the times that they perceived as less bothersome for others. Similarly, negative impacts of visitor traffic have not been an issue for these labs so far.

Concrete discussion of material and waste was also less prevalent in the examined cases than for the built environment and networks categories. Still, endogenous aspects were revealed. The sites are described both as re-users of materials from local waste streams or within their own material-product production flows, as well as generators of waste for disposal in the larger urban waste management system (PRENDEVILLE et al. 2017, UNTERFRAUENER et al. 2017). While their production activities are both influenced by and impact local materials' use and re-use, one Hamburg case demonstrates the reliance on the overall urban waste disposal system. In this case, the lab manager collects and transports recyclable waste materials from the lab themselves, as these would otherwise not be be separated from non-recyclable waste in the city's commercial waste pick-up.

The networks category has a high level of endogeneity. Especially in exchanges with the Hamburg Open Lab cases and in the exploration of their actor networks, it became clear that some small-scale production sites seek out other networks in the city and play a major role in bringing together diverse, interdisciplinary actors from the larger community and fostering their cooperation. This does not necessarily happen organically, though, and others have found cases with more insular approaches and describe barriers to engagement and inclusivity, such as cost to users and capacity of lab manangement (VINODRAI et al. 2021).

For our network factors, we differentiate between the interaction with these networks and their location in proximity to a production site because it cannot be demonstrated so far that the presence of a small-scale, accessible production site such as a Fab Lab or makerspace acts as a driver or barrier for further production, educational, or cultural/social organisations to locate or operate within a certain area. This is rooted in our focus on the current situation at existing sites, where the presence of certain network infrastructures acts more frequently as a siting criterion or is used as a resource according to the site's goals related to, e.g., marketing, reputation-building, or increasing the user base. However, we consider this a tentative classification and see potential for the location factors in this category to be endogenous when considering implementation of accessible production sites at larger scales.

6 DISCUSSION AND CONCLUSION

From an urban planning perspective, these factors highlight the multi-layered nature of urban integration of spaces of production, which must go beyond purely spatial considerations, as well as the bi-directional impacts of these spaces in and on the local urban and social fabrics. With respect to the potential contribution to urban resilience in the long term, we posit that small-scale, accessible, digital production sites, such as Fab Labs or makerspaces, hold potential to address certain weaknesses of urban resilience efforts. Wardekker (2021) describes the risk of the Resilience Planning framing to fail in "dealing with social aspects" and of the Resilient Community Development framing to over-emphasize those who "can afford to think about the future."

Enagement of the public is a key defining element of this type of production. This engagement is the significant connector to the Resilient Community Development framing. The factors show that FabLabs are more than economic projects but contribute to the socio-economic development of the quarter. This also means that different actors and responsibilities come together (schools, social workers, universities etc.) with, in many cases, differing goals (education, workforce development, inclusion, etc.). The low barrier to

entry and participation in production that these labs and makerspaces share can contribute to the broader community's exposure to resilience discourses and enable the uptake of more resilient practices, in accordance with the social innovation role assigned to them by current research (e.g. GARNIER/CAPDEVILA 2023) and in the Fab City context (DIEZ 2012; DIEZ 2016). In urban development and social terms, this finding implies a need for economic development and community development organisations to take small-scale, accessible, digital production sites into consideration for funding or other incentivisation in order to take advantage of their non-economic benefits. The intensive networking work done by the production sites themselves within their communities implies future potential for them to act as anchors or draws for other community development organisations and resources. The necessary scale of implementation to achieve this and the concrete socio-economic impacts for surrounding neighborhoods should be explored further.

Also with regard to integrative potential, the factors related to materials and waste highlight the role of small-scale, acessible production sites as part of a *circular* local production ecosystem, as envisioned in the Fab City concept. A production site must not necessarily explicitly express circularity goals, but many do (e.g. UNTERFRAUENER et al. 2017, PRENDEVILE et al. 2017). The two Hamburg case studies provide good examples of this. Not only are products developed using recycled materials or for re-use, both Open Labs are active in the development of circular business models that seek to increase access to circular products and material flows. Thus, they are not only users, but supporting supply of local materials and useage opportunities in the larger urban area.

This reseach highlights weaknesses of urban planning's formal structures to enable such bottom-up forms of resilience development. Within the Resilience Planning framing, Fab Labs are an example of an experimental approach that can challenge traditional system assemblies and demonstrate new decentralized arrangements. In terms of planning policy and regulation, the capacity of these spaces for fluid and changing types of production calls into question the strict functionalism of traditional zoning and usage practices in urban planning. These production sites are not pre-designed and pre-ordained production lines in a traditional industrial sense, but intentionally adaptable and multi-functional spaces. Conventional zoning and useage regulatory structures struggle to incorporate this flexibility, although flexibility is what Resilience Planning calls for.

The factors of urban integration presented here provide only an initial overview of aspects which can be considered at the intersection of small-scale production and urban planning and development concerns. In order to identify and elaborate more concretely the impacts of these factors on the implementation of labs and makerspaces in existing urban neighborhoods and the impacts of these sites on the neighborhoods themselves, further research is needed. The factors must be verified and validated through empirical studies both of existing production cases as well as of city-level strategies such as the Fab City initiative. This is planned as a next step in the Fab City project in Hamburg.

In addition, we hope to draw attention to the need for further development of planning and governance instruments that respond to the systems challenges and potentials of the integration of urban production in mixed-use areas. The issue of gentrification as it relates to urban production and manufacturing should especially be investigated in greater detail. Not only must industrial gentrification, the movement of these users out of existing neighborhoods, be better understood, but also social gentrification, or the extent to which the production sites themselves may contribute, whether intentionally or not, to the dismantling of historical neighborhood social networks and structures (see e.g. DE BOECK/RYCKEWAERT 2020; MARTIN/GRODACH 2023; SCHROCK/WOLF-POWERS 2019). These debates tie into the larger discussions of the trade-offs of the evolution and equilibrium perspectives of urban resilience which Wardekker (2021), among others, also describes. For small-scale, accessible, digital urban production to be implemented as a tool to support overall urban resilience in the long term, these risks must be made explicit and policy and practice adapted to respond to them.

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Smart Cities and Infrastructure Development: A Case Study of the Gauteng City Region in South Africa

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1 ABSTRACT

Infrastructure development is a critical enabler of socio-economic development and contributes to raising the quality of life through the creation of social amenities and consequently contribute to macro-economic stability. Smart city has recently become a buzz concept that leads the way to an inclusive and democratic urban future planning and urban growth. In South Africa, generally, the communities are in search of urban prospects and as a result are disadvantaged as an unintended consequence. This is primarily due to a lack of bulk infrastructure services such as sanitation and water treatment, which is unable to cope thereof, necessitating Smart City to become a high-impact, compact, complex, mixed-use urban development that is designed to deliver urban prospects to a more marginalized periphery. Whilst various components and processes which play a vital role in developing or creating smart cities have been discussed in detail over the years, there is still a need to demonstrate the role and interventions towards the economic development of the City of Johannesburg, particularly in urban areas in the Global South. Consequently, this paper explores the impact of Smart City initiatives on socio-economic development in the greater Gauteng City Region, South Africa. The work adopts a phenological case study research design and a qualitative approach to gather data through a series of desktop research and literature reviews. The data was analyzed using thematic analysis as a research method to reveal themes on inclusivity and access and Excel software package was applied to obtain descriptive statistical results. Also, a systematic review of the literature to analyze Smart City strategies embedded in the spatial development framework. Findings reveal the crucial role of effective urban development planning in the economic infrastructure value chain. Successful Smart City implementation contributes significantly to economic growth, diversification, and improved access to modern technology. The paper concludes further that smart city initiatives and state investment in infrastructure contribute largely to economic growth as a benefit, as well as diversification of the economy, thereby providing access to modern technology. The study recommends an inclusive and integrated policy framework for resource allocation aligned with growth and development in Smart City initiatives, ensuring a cohesive approach.

Keywords: Economic Growth Investment, Infrastructure Development, Smart Cities, Social Amenities, Spatial and Urban Planning

2 INTRODUCTION AND BACKGROUND

The global population today continues to shift towards urban areas and expand rapidly in developing countries and catalyzes significant economic and social development and transformation, hence modernization of infrastructure is significant for future economic competitiveness and play a very pivotal role in accommodating the expanding population in the urbanizing environment. Literature research study shows that smart cities provide comfort to the people as they migrate from rural to urban cities, hence Ahad, Casalino & Bhushan (2023) argue that smart cities gives practical solutions to the myriad of challenges that the communities are faced with thereby providing some benefits such as clearer and better coordinated, integrated planning and development. Furthermore, to ensure that the cities are able to effectively use its energy renewable and green technology and building. Smart cities would need to become the drivers of rapid, inclusive, and sustainable economic growth and transform spatial inequities, thus Vinod (2022) views smart city as constantly evolving with innovation and creativity, as well as citizen engagements through city integrated development planning. The notion of infrastructure development is consistent with international best practices for sustainable and robust economic development based on an alternative growth path and has

immense capacity and potential to propel and create new impetus to grow the economy, and all these entails improving planning, sanitation waste-water management and other social amenities (Chatterjee et al. 2023). This is especially true for countries that were severely devastated and constrained by the history of various forms of urban and spatial planning inequalities. In the South African perspective, infrastructure development is linked to the social economic context, this therefore denotes that inequalities, poverty, and unemployment have a direct impact on the sustainability of smart cities and urban populations, as well as people's behavioral patterns which is a phenomenon that is becoming prevalent in the global south. Although the (National Development Plan 2030) provides a clearer vision of how South Africa intends to eliminate poverty and reduce these inequalities, it further guides on a set of normative principles that will create a conducive space, livable environment and sustainable to support economic opportunities, as well as social cohesion. The concept of a smart city has evolved and has gained much more global popularity as a fundamental mechanism to address urbanization, environmental concerns, as well as economic growth, particularly with the technological demand as technology advances., hence according to Adriano et al. (2021) becoming innovative and creative cities is important to ensure that cities are able to address its challenges of providing services to its citizens.

In view hereof, it is imperative to take into cognizance that a smart city is not necessarily an information and communication technology conceptualization of a modern city, it is however based on principles that underpin a truly sustainable approach to nation and city building, as well as the need for social, economic and cultural inclusivity, although according to McKenna (2021), Information technology, access to public data are critical element that contributes to the making of smart cities, as results a city that is divided along economic, ethnic, and cultural diversity cannot be sustainable, hence the notion of a smart city requires many dimensions of a city building, and not just a city operating of a comprehensive enabled information and communication technology platform. This paper has therefore explored frameworks that are used to guide the development of smart cities and identified relevant literature and systematically reviewed such for relevance to gain meaningful insight into the data.

3 CONTEXTUAL FRAMEWORK

3.1 Smart City – Origins

The introduction of information communication technology infrastructure necessitated the need to originate the concept of smart cities in the early 1990's with cities starting to regard themselves as cities with smart collaborations and focused on infrastructure-based services using ICT and drive their smart city agenda which often in support of their market expansion strategies (Department of Corporative Governance, 2021).

The ICT investment is based on digital, transition and economy in which citizens have access to knowledge based and sophisticated, information communication technology. In South Africa, in particular the Gauteng City Region, spheres of government have partnered with private sectors and universities to impart digital skills and build centre of excellence in the innovation eco-system with most households, in Gauteng having access to internet connectivity and consequently impact positively in their lives (SACN. 2016). In this regard, the development of smart cities results in various challenges and according to Das (2013) these modelling challenges includes lack of sufficient and reliable data influencing smart city development.

The concept of a smart city has a plethora of definitions with varying conceptual interpretations that often substitute the term smart with an alternative description such as digital or in certain instances intelligent (Smart Cities, 2023). This definition is evolving throughout literature within the smart city paradigm, hence many cities across the globe invest in the realm of information technology communication to ground the smart city definition (Mallory and Baches, 2022), however, with a particular focus on the fourth industrial revolution technologies. Table 1 below shows some list of different scholar's interpretation and meaning in relation to smart city definitions.

Studies show that there is no consensus on the definition of the concept of smart cities, however many definitions have one centrality to information and communication technology which is deemed to be critical in facilitating systems dimension that affect the lives of residents within the city or town. Smart cities change the development and spatial city planning and how it is managed over a short term which enables cities to become smarter in the long-term. The figure 1 below as adapted from (Joshi et al., 2016) illustrates smart city dimensions that enable it to function as different aspects that make an urban system.

Source	Definitions
Townsend Anthony, 2013	A city where information technology is being incorporated into services that affect urban problems. "Smart city perspective places where information technology is combined with infrastructure, architecture, in order to address the social, economic, and environmental problems that the citizen is experiences in daily basis." Townsend, 2013 outlines these perspectives in relation to information technology as a mechanism to address societies social problems in the smart city.
McKenna Patricia, 2021	Smart city definitions and concepts are based on perspective regarding smart cities and regions which are definitions for urban theory in relation to smart cities.
Harrison Colin and Abbott Donnelly, 2011	A city that has "Urban Systems models that are capable of helping citizens, entrepreneurs, civic organizations, and governments to see more deeply into how their cities work, how people use the city, how they feel about it, where the city faces problems, and what kinds of remediation can be applied".
Rana et al., 2019	Smart city can be defined as "Technologically advanced and modernized territory with a certain intellectual ability that deals with various social, technological, economic aspects of growth based on smart computing techniques to develop superior infrastructure constituents and services".
The British Standards Institute (BSI, 2014)	Smart cities are "the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens".

Table 1: Smart City Definitions

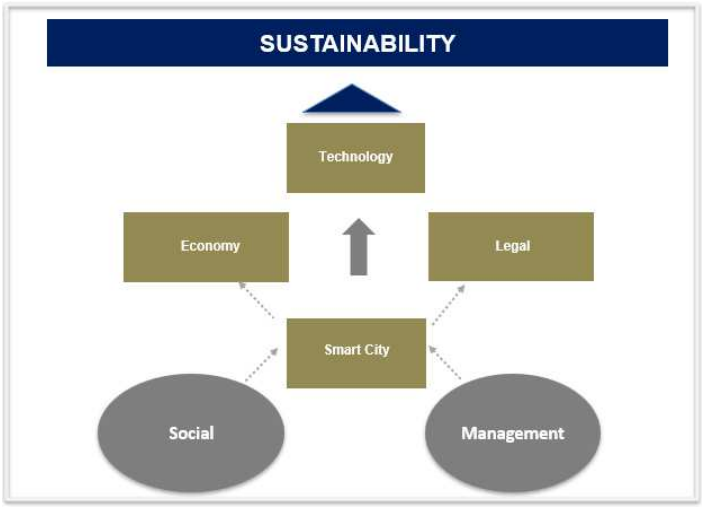


Figure 1: Smart Cities Dimension. Source: Joshi et al., 2016.

The figure above illustrates smart city dimensions that enable it to function as different aspects that make an urban system. There is a wide consensus of accepting the dimension of smart city concept, hence the development of city contributes to the investments in economy, technology, social, legal, and management.

3.2 Smart City Benefits

3.2.1 Smart City Global Perspective

Infrastructure is regarded as one of the very most powerful driver of economic and social growth in urban planning in the global south, hence literature studies reveal that the concept smart city is generally growing with time with its focus now shifted to generation of technology enabled and smart city led which is mainly people centric. These smart cities emergence, according to Tooran (2021), Global trends of smart cities as a results of information communication technology which plays a major role in the transformation and changing of urban life and space, hence cities and regions around the world have taken initiatives to prioritise integrated urban planning, economic development and productivity growth.

In the context of the global perspective, the concept smart city is essential in the development of the eco-system which ensures that citizens in the cities have access to provision of social amenities, security and safety including health environment. The table 2 below illustrate the best practices of the global and African perspective.

Table 2 illustrates Smart Cities best practices of the global, African, and South African perspective. Further highlights some critical success factors extracted from global smart cities. A few cities in Africa have taken a serious step on investing in ICTs for growth and development.

In the developed countries, information technology and innovation is central to the success of the smart city through introduction of big data and artificial intelligence, which plays a major role in the development of a smart cities and urban planning as shown in figure 2.

City	Key features and lessons to be learned
Key features and lessons to be learned from leading smart cities:	
Singapore	Developed an entire smart city ecosystem supported by infrastructure, technologies, policies, culture, and capabilities.
Búzios, Brazil	The Búzios Smart City project created a smart grid that generates renewable energy.
Key smart city features and lessons from an African perspective:	
Lagos, Nigeria	The city designed the national Nigeria Smart City Initiative, which has managed to secure significant investment from local and multinational ICT companies.
Moka, Mauritius	Moka is a relatively new city. It is being built around smart city technologies as a means of boosting the economy and improving the standard of living.
Key smart city features from South African perspective:	
Waterfall, South Africa	Waterfall City as the "the largest mixed-use development in South Africa". It gives the community the possibility of enjoying the convenience of work, life, and lifestyle all in one environment. Smart cities provide a new and improved transport networks Using wireless electronics and communication technologies, users and consumers are provided with a "smarter, safer and faster way to travel". Smart transport systems drastically reduce commuting times.

Table 2: Smart Cities Best Practices: Source: Maphangwa and van der Waldt, 2023

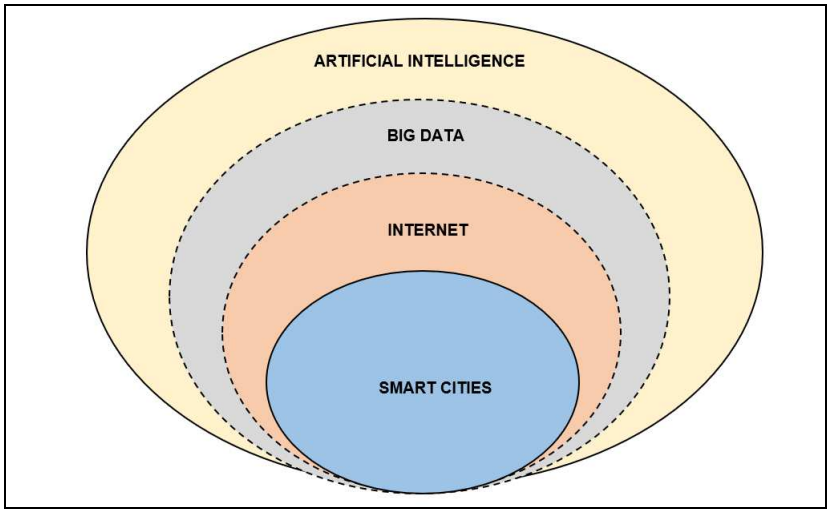


Figure 2: AI-Based Services for Smart Cities and Urban Infrastructure. Source: Kangjuan, Lyu et al., 2021.

The figure above shows that smart cities is an important phenomenon and provide a new model of urban governance which is able to protect the cites ecology and environment hence urban planning and big data and internet is a critical strategic decision making to the cities development.

3.2.2 Smart Urban Planning System in African Cities

The notion of spatial planning, particularly in the African continent is critical to ensure sustainable development for a country since it could impact the environment and socio-economic aspects. According to Chavunduka et al. (2022), the growing population and rapid migration in the African continents require adequate and reliable infrastructure that meets the demands of social amenities such as affordable human settlement and employment opportunities, hence spatial planning systems inherited during the colonial era are not suitable to African realities of rapid urbanization and change of spatial inequalities.

African cities are faced with greater challenges of urban planning and development arising from rapid urbanization and increasing population, hence developing countries have considered new initiatives and approaches, such as the smart city concept. This asserts that urban planning provides the basis for the development of all towns and cities including access to digital data and information communication technologies which are integral parts of geo-spatial information.

Smart cities create a wealth of opportunities and impact people's quality of life and directly improve citizens' convenience. Thus, initiatives to adapt to changing technological demands such as public Wi-Fi have a direct positive impact on people's quality of life. According to Gora and Banji (2017), the African urban growth rate and urbanization are rapidly growing at 3.5% with the majority of the African population sitting at 52% already living in towns and cities. These urbanizations and rapid African urban population are projected to increase to above 50% by 2030, hence the development of large cities and towns provides

opportunities for economies of scale and necessitates infrastructure investment to respond to the increased demand such as water sanitation, energy efficiencies and effective and efficient provision of waste solid management. An African smart city that is sustainable should be geared towards people centric approach premise on the principle and foundation of information communication technology, sustainable infrastructure development and social security, peace, and safer communities. Figure 3 below illustrates the dimensions and components of a smart economy in a smart African city, which provides opportunities for investment and economic growth.

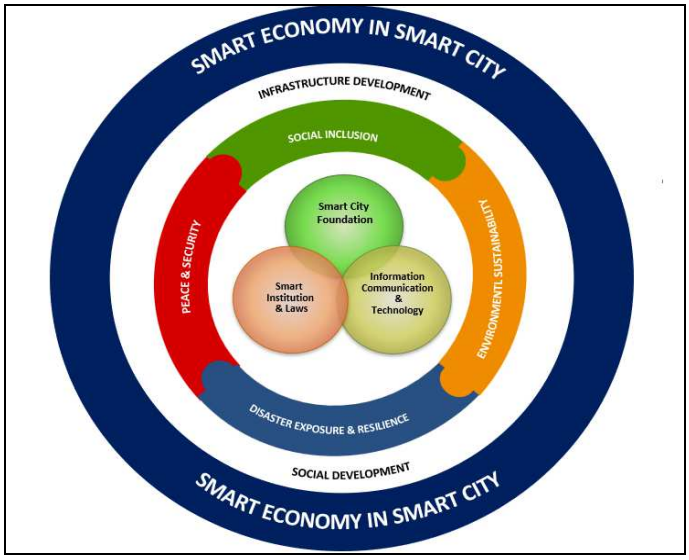


Figure 3: Smart Economy in Smart African Cities Conceptual Framework. Source: Mboup, 2017.

The figure above shows the dimensions and components of a smart economy in a smart African city, which provides an advance research institutes that enhance the telecommunications infrastructure, which contribute to the creation of employment and the advancement of advanced technology.

3.3 South Africa's Approach to Smart Cities

South Africa is a constitutional democracy with three spheres of government, which are national, provincial and local. These three spheres of government are distinct from one another and are interdependent. The Constitution of South Africa grants each one of these spheres the autonomy to exercise its powers and perform functions within the required parameters. South Africa's economic outlook is perceived to be steadily declining in growth rate as a result of domestic and global constraints. This is attributed to inadequate social infrastructure factors such as water shortages, serious drought and labour unrest, as well as the challenges for electricity generation, transmission and distribution which is aging infrastructure including, tighter fiscal policy and policy uncertainties, which inhibit private investment. This necessitates South African government cities and towns to embark on a drive to address the legacy of colonial and apartheid socio-economic and spatial engineering and adapt to a set of global forces that are redefining global economy.

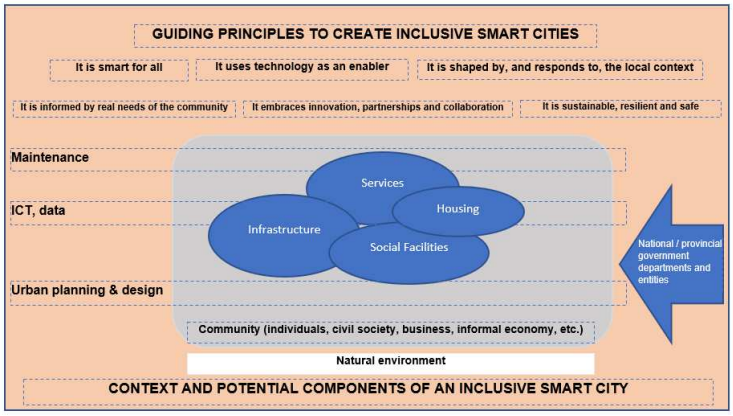


Figure 4: A South African Smart Cities Framework. Source: Department of Cooperative Governance (DCoG), March 2021.

The Department of Corporative Governance, 2021 provides a clear approach and understanding regarding Smart City initiatives and focused benefits to different municipalities that are entrusted with the responsibility to initiate smart cities. These initiatives should be direct and deliberate to improve the lives of the people who are residing in that city or town. Figure 4 outlines a detailed example of smart city components, collaboration and relevant role-players participating in a Smart City initiative.

The National Development Plan (NDP) 2030 provides a long-term vision for South Africa and defines a desired destination, specifically aimed at eliminating poverty and reducing inequality by 2030. The figure above further depicts an inclusive smart city that should incorporate smart technologies to improve the citizens‘ standard of living, urban processes, and services efficiencies to meet future needs in relation to socio-economic and environmental issues in a smart city, as well as smart people as defined in the United Nations Economic Commissions for Europe 2020, which foster sustainability across the environment, economic social and cultural dimensions. It is for this reason that there is more value in the usage of technology. It is therefore in this context that smart cities encourage the development of new ideas, as well as innovative solutions to increase employment and decrease the city inequalities and skewed land distribution.

The concept smart city and development model are gaining momentum necessitating many great cities globally and locally to be in the path of becoming smartest cities. Whilst South Africa is a developing country, is constraint with increasing population growth rate, high unemployment, constant demand for basics services, public transport, energy water and provision of health care services amongst other, hence metropolitan cities in South Africa have different challenges requiring specific solutions.

Sanjay (2019), argues that in South Africa, the largest mixed-use development is the Waterfall City, which is situated, adjacent to the Mall of Africa, located between Johannesburg and Pretoria in the Gauteng city region and essentially provides an integrated social amenities, and it is regarded as an enjoyable place for citizens to work in and live a fulfilled lifestyle. In the same vein, Sandton eco smart city which is the financial and commercial area in the City of Johannesburg, is also regarded as a world class precinct with sustainable, smart choice for business, transport, institutions of learning, health, as well as residential area for the citizens. In terms of transport integrated system is close proximity to Randburg, Rosebank, Bryanston and Hyde Park. In this regard these model of smart city in the Gauteng city region advance compaction, residential densification, in-fill development and mixed land uses within the existing urban fabric that promotes walking, as well as cycling. This further includes an integrated public transport nodes which is reliable, accessible and safe necessary to give effect to redress the apartheid spatial planning, in the Gauteng city region. It is therefore in this context that the (National Development Plan, 2030) provides clear initiatives to advance urban restructuring and revitalisation objectives in the rural and urban landscape development boundaries in South Africa.

Identification	
Systematic Literature Review	The first step was to conduct a literature review which in essence covers some critical concepts for the study which includes Smart City, sustainable infrastructure development, smart economy and how such apply to the study area of Johannesburg city region intervention. The approach in this study highlighted the benefits and challenges concerning people, information communication technology, provision of basic infrastructure services and policy context in the smart cities paradigm and how these favors a sustainable outcome and intervention in the new shape of urbanization, modernization and reindustrialization.
Screening	The concept of Smart City has become a buzzword and has evolved. Empirical evidence and studies reveal that there is constantly rising published papers on smart cities, however, the high population growth rate in the South African perspective, has an impact and strain on the infrastructure investment in the sense that the current level of infrastructure is not equivalent or meeting the demand on required social infrastructure, as well as provision of services.
Included and eligibility	This study outlines the findings using and analysis of literature in the methodology and design considering the preferred reporting items for systematic reviews and meta-analyses (PRISMA) TOOL. The published papers cited were screened and checked for relevance in relation to the concept of smart cities and infrastructure development.

Table 3: Study Research Methodology

4 METHODOLOGY

The research design for this paper entails case study and desktop approach incorporating various methods of data collection. This process of data collection and analysis for this paper is described in the following table. In this article, the researchers adopted “the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA)”, as an item checklist, that filter relevant information using the four criteria to guide

the researchers in their research study: identification, screening, eligibility and inclusion. This section introduces the methodology followed in this study, as depicted in table 3.

Table 3 illustrates the methodology followed in this study for data collection and analysis. The study adopted "the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA)", to screen or filter relevant information. It is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses.

5 RESULTS AND DISCUSSIONS

This paper finds that the concept Smart City has various meanings and interpretations. As such, in the context of this study, research is intended to increase the efficiencies of urban infrastructure development and management in the Gauteng city region through developmental solutions and possibly technologies, as well as promoting smart and green technologies. This is critical in light of changed climatic conditions and the need to promote a sustainable environment and green development. At the centre of this infrastructure value chain, is the provision of water, sanitation, and energy efficiencies which directly affect the livelihood and health of the people within the regions and cities. The study shows that rapid urbanization and growth in population rate continue to dominate the trends across the globe and South Africa, is no exception to these trends.

Gauteng City Region

Gauteng is South Africa's smallest but most densely populated province, South Africa's financial capital and most important economic node, producing 34% of the national GDP on 1.5% of the country's land area (GSDF, 2030). The province constitutes 1.4% of the total land area of South Africa, making it the smallest province and also the largest urban economy in Africa. Given this analysis, it is imperative to note that Gauteng does not function in isolation, as it has strong economic, movement, and functional linkages with towns and cities and the geographical space known as the Gauteng City-Region (GCR). The GSDF 2030 is a long-term spatial policy of the Gauteng province that provides a long-term spatial vision for the GCR. It has three Metropolitan Cities, which City of Johannesburg, which greatly enjoys the largest population, size and economy with total population of 5.4 million and contributes 15% of the national GDP, the second City is Ekurhuleni which is an economic hub within the Gauteng city region and contributes to over a third of the National GDP and the third being City of Tshwane which is situated in the northern part of Gauteng and is the advanced commercial city in Africa and contributes 10% of the South African GDP (Maphangwa and van der Waldt, 2023). The figure 5 below shows Map of GCR.

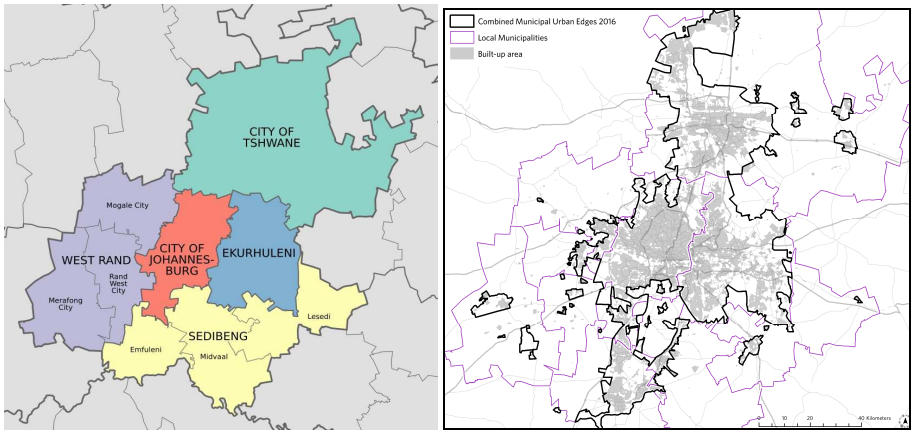


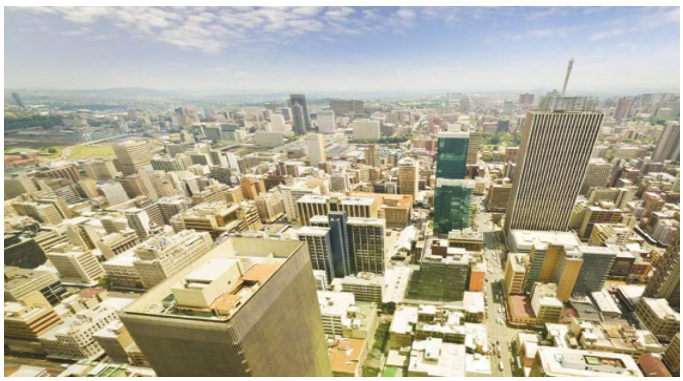
Figure 5 (left): Map of GCR. Figure 6 (right): Municipal Urban Growth Management. Source: Gauteng Spatial Development Framework, 2030

The figure above shows map of Gauteng City Region with five metropolitan cities which contributes to development and economic growth.

The City of Johannesburg continues to experience infrastructure pressures as a result of this fast-growing population and migration, and as such the spatial urban planning of the city plays a pivotal role in shaping and defining the infrastructure layout, use, and provision to ensure a sustainable outcome for Smart City. This is evident from the map on Municipal Urban Growth Management shown below as extracted from the Gauteng Spatial Development Framework 2030.

The infrastructure capacity is faced with enormous pressure and backlog because of migration and growing population rate. This further shows that Gauteng province and its municipalities have demarcated urban growth boundaries with the view to reduce urban sprawl and infrastructure investment management to ensure social cohesion and integration. In this research study, a particular reference point is made to the City of Johannesburg in which its infrastructure development and growth fall within this pressurized category of servicing and providing basic needs such as water, electricity sanitation, thus this paper shows a close relationship between Smart City and infrastructure development.

This study focuses on the Gauteng City Region, which is an integrated cluster of cities, towns and urban nodes, with particular attention to the City of Johannesburg, South Africa. The city reflects the challenges and opportunities of South Africa's economic demographic, social and political transformation. The figure below shows an aerial view of the City of Johannesburg.



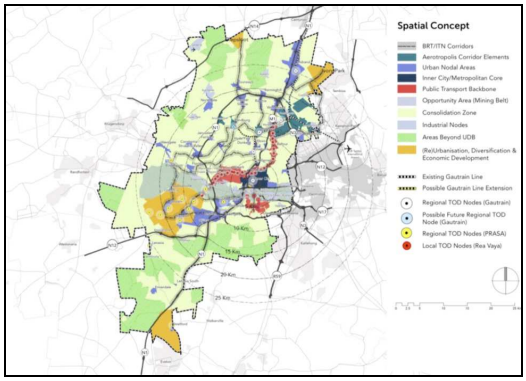
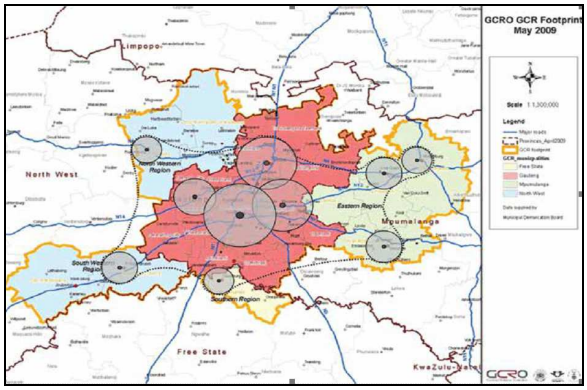


Figure 7 (left): South Africa's Global Gateway: Profiling the Gauteng City-Region's International Competitiveness and Connections. Source: Joseph Parilla and Jesus Leal Trujillo, 2015. Figure 8 (right): Spatial Planning Map. Source: GSDF, 2030.

The Growth Development Strategy 2040 depicts the City of Johannesburg as a polycentric city, with high-intensity nodes, incorporating both residential and commercial land uses. These nodes, large and small, will anchor the spatial structure of the city's urban transformation which is achieved through constant improvement in planning and design, as well as in public infrastructure investment. According to Wray (2010) as cited in the GCRO (2013), these spatial considerations which are considered polycentric in the Gauteng city region are depicted in figure 9 below.



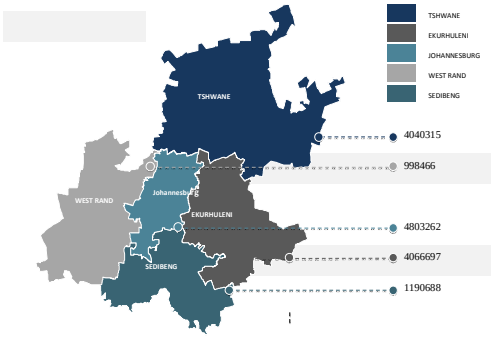
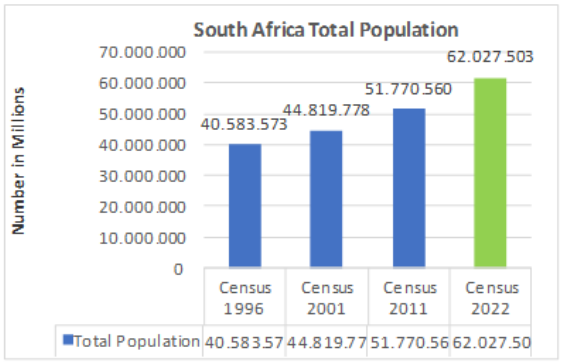
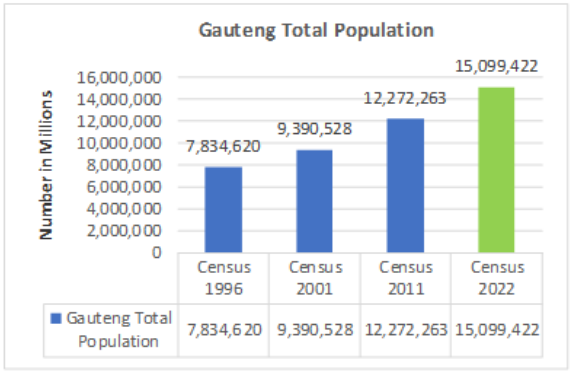


Figure 9 (left): Map (GCRO). Source: Brian and Harold, 2013. Figure 10 (rightGauteng Municipalities Population Growth. Source: Stats SA Census, 2022.

The City of Johannesburg, in its Development Plan Strategy 2040 concedes that the spatial inequality is a result of South Africa's legacy of apartheid planning which largely played a major role in urban inequalities and race-based towns. The new cities across the globe are faced with the impact of a growing population rate and urbanization. This population growth rate in the City of Johannesburg accelerates the challenges of urban poverty, housing, and water shortages, as well as electricity distribution to city residents (IDP, 2021). The below graph 1 and 2 shows the total population of South Africa and Gauteng Province by Census 1996–2022.





Graph 1 (left): South Africa Total Population Statistics. Source: Census, 2022. Graph 2 (right): Gauteng Province Total Population Statistics. Source: Census, 2022.

The graph above illustrates the population growth by Census over a period of ten years, 1996–2022. The results indicate that there is population growth or increase in the country. For the past 30 years, since 1996, the population increased from 40 583 573 to 62 027 503 in 2022, and this represents a growth rate of 4.1%. As such, the biggest growth rates were observed between 2011 and 2022 at 1,8%, while the rate between 2001 and 2011 was 1,4%. For Gauteng Province, since 1996 the population increased from 7 834 620 to 15 099 422.

Fig. 10 illustrates the 2022 Gauteng Municipalities population growth totaling to 15 099 422 over time. Given the growing population, this map shows that the province contributes 2,2 trillion rand (33,1%) to South Africa's GDP, the breakdown of population per municipality in the city region is also shown in the below map.

The continuous pressure for urban growth leading to lack of bulk infrastructure such as sanitation, as well as outfall water treatment works which is unable to cope with demand pressures in the City of Johannesburg gives rise to the need for regional Smart City initiatives (IDP, 2021). Notably, the initiative of Lanseria Smart City which is a high-impact, compact, complex, mixed-use urban development designed to deliver urban prospects to a marginalized periphery (GLMP, 2020), which is an urban intervention towards inclusive sustainable urban future as depicted in the below map.

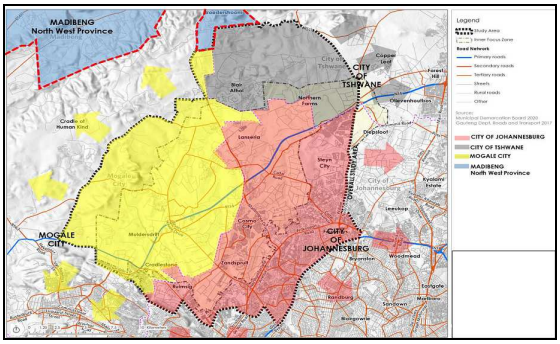


Figure 11: A Greater Lanseria Master Plan 2020. Source: Gauteng Provincial Government, 2020.

In view of the data presented and illustrated above, it is evident that the City of Johannesburg embraces the Smart City concept as shown through its integrated development plans and it can locate itself firmly in the global space with clear aspirations of further sustainable development and growth.

6 CONCLUSION AND RECOMMENDATION

This paper has argued that smart cities are diverse and complex in nature, and therefore this concept is not limited to a local phenomenon in the context of Gauteng city region but exists across the globe and has many economic benefits. Priyankan and Singh (2023) state that smart cities play a very pivotal role in poverty reduction and can make the city a much more enjoyable place to live and ultimately benefit their citizens, given that sustainable smart cities have multiple features aimed at enhancing cities competitiveness and economic growth.

This research paper largely focused on infrastructure as an enabler of development within the smart cities, thus effective development planning initiatives and strategies should be integrated in all dimensions across all spheres in order to yield positive suitable outcomes and economic benefits and growth, for instance, the provision of water services, and sanitation, wastewater treatment, and bulk sewer cannot operate in isolation of electricity provisions, as well as skilled or smart people in the smart economy. The integration of all these multiple dimensions will ensure that greater efficiency is achieved through improved communication technologies, as well as the capability to use data extensively to manage both supply and demand.

In view thereof, in the context of policy implication plays a vital role as a guiding tool for the policymakers who are engaged with smart cities development initiatives in the developing countries. In the same vein, effective policy management and implementation is imperative in assisting cities to understand the possible challenges that the cities are likely to face and consequently assist cities in policy decision to ensure sustainable development. Smart city approach plays a critical role in growing the economy, and reduce the spatial inequalities, as well as unemployment hence urban planning correlates with economic growth as well infrastructure development and as a result positively contributes in improving the quality life of the citizens. Smart cities have necessitated urban planners to rethink about the critical role of all stakeholders and not only national, or local government in the formulation of urban policies and implementation in the smart cities. Kundu, Sietchiping and Kinyanjui, (2020) argue that whilst the concept smart cities are engines of economic growth and innovation such economic growth needs to be sustained through a well-co-ordinated policies to guide and support the cities and regions in the management of their urbanisation pattern. Therefore, the implications for urban planners is to ensure that there are well developed smart cities economic framework and development models that will mitigate the challenges of inequalities and urbanisation.

This paper draws some lessons learnt on cities with greater challenges of inequality and urban sprawl, as a consequence of migration from rural to urban cities. Some of the lesson learnt relates to how smart cities and infrastructure development are vital in the creation of sustainable development thereby improving people's quality of life. It is in this context that infrastructure development lies at the heart of promoting inclusive economic growth and social equity (National Infrastructure Plan 2050), which intends to transform the nation's economic landscape, and structural urban planning changes by reducing spatial inequalities and strengthening the delivery of basic infrastructure service. The infrastructure investment in which resources are allocated within spheres of government is likely to get diluted as a result of poor management of the provision of services to the citizens, as well as possible maleficence that may arise during the implementation process.

This paper concludes that any policy intervention related to urban planning and smart cities of a country should be aligned to specific country local context so that it is able to respond to its specific local needs, opportunities, as well as challenges. Smart cities should not only be viewed in the context of information technology but should also include or consider other dimensions in the value chain such as a suitable climate conditions and environment in which people can learn, have knowledge through continuous interaction in the smart cities, as well as urban management. In this regard, this paper recommends that an effective infrastructure delivery value chain and expansion within the sustainable smart city requires a consolidated governance policy framework to guide how resources are allocated across all sectors of the economy to align with the growth and development path, given that the urban and spatial planning sectors need a growing economy.

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🏆 *reviewed paper*

Smart Cities through Online Dating and Sustainability – Responsible Leadership in Smart Cities

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1 ABSTRACT

This research is the link between Online Dating Platforms, Sustainability and Smart Cities. It adds the fourth pillar of sustainability to the traditional three pillars: social, economic, ecological and fourth: online life. The research question is: How can Online Dating Platforms contribute to Smart Cities? New technologies in Online Dating Platforms, especially Artificial Intelligence, are changing the way Online Dating Platforms are used by daters. They are also managed differently by specialized organizations, and therefore are elaborated for the future. From the standpoint of sustainability, innovation management and entrepreneurship development the Online Dating Business is bringing a positive venue to Smart Cities through Sustainability and Happiness. Hence, this study investigates how 'sustainability', 'responsible leadership' and 'online dating platforms' are linked, and more specifically, how to avoid the uncertainty involved in new encounters in online dating platforms and/ or in business. Additionally, the study makes the connection between online dating platforms' love and online dating platforms' distrust and lies. To reach this goal, the author uses data collected in interviews with xx respondents from January 2024 until April 2024, and from previous studies from 350 respondents about online dating platforms from 2020 until 2023, and with 197 respondents about responsible leadership from 2015 until 2019. The research identifies elements of creativity and imagination in online lying that could be applied to further enrich communication on the Internet and in Smart Cities in general. It is about Responsible Leadership in Smart Cities. The fourth pillar of sustainability - online life - is added to the three traditional pillars: social, economy, and environment. This is innovative regarding Social Innovation, enhancing social integration, human relations, happiness in general and a creative way to improve Smart Cities.

Keywords: responsible leadership, digitalisation, online dating, smart cities, uncertainty avoidance

2 INTRODUCTION

The purpose of this study is to explore how 'online dating platforms' are related to 'smart cities' (Kaufmann et al., 2020), 'sustainability' (Vrontis et al, 2020), and 'responsible leadership' (Maccoby, 2011; Schinzel, 2018; 2019; 2020) seen from an innovation standpoint (Leonidiou et al, 2020), and, more specifically, how to mitigate the uncertainty (Hofstede, Hofstede, and Minkov, 2010) involved in online dating platforms and business encounters. The research question is: How can Online Dating Platforms contribute to Smart Cities? Research about 'Smart Cities' has been in the focus for the last years (Albino et al., 2015; Angelidou, 2015; Chamoso et al, 2018; Lwakatare et al, 2015; Senapathi et al, 2018), the link to 'online dating platforms' is innovative and the author's contribution to knowledge.

A by-product of this question is the proposition that the imagination and creativity used in personal misrepresentation on online platforms have the potential to be used in the process of the recruitment of new employees in organizations.

Online Dating Platforms have seen significant increase in use in the last years. With the coronavirus pandemic confining people to their homes, they went online to socialize in general, and on Online Dating Platforms in particular. Once the pandemic was over, they remained online. Research and experience have shown that people are not always completely honest, nor in presence, nor online, by not always telling the truth about themselves. While some might see misrepresentations as 'lies,' others may see them as 'imagination' or 'creativity,' and yet others as the mis-representer's 'second life.' Hence, creative misrepresentations produce new useful ideas for the future, at universities among others (Papaleantiou et al, 2014).

How much responsibility lies with the management of the online dating platforms to ensure the security of their users through 'responsible leadership' and overcoming 'uncertainty avoidance'? Deception comes from lies, told by the online partners (Markowitz and Hancock, 2018). Are these partners lying or are they using their 'creativity' and 'imagination'? Do they use misrepresentation of personal attributes such as age, gender,

photos, salary, availability and other characteristics to allow themselves to experience a 'second life' of another person, online, and sometimes in reality?

The research question is: How can Online Dating Platforms contribute to Smart Cities? What is the link between Smart Cities, sustainability, responsible leadership, and online dating platforms? A secondary associated question is: How can one mitigate the uncertainty that exists in new encounters on online dating platforms? The study contributes to knowledge by linking and offering a comprehensive model of the relationships between Smart Cities, sustainability, responsible leadership, online dating platforms and uncertainty avoidance.

While every new encounter, online or in presence, dating or while negotiating, brings uncertainty, the question is how to mitigate this uncertainty and to increase the safety for the users. Additional questions come to the researcher's mind, such as: While digitalisation is the big winner of the 2020/2021 coronavirus pandemic (Schinzel, 2021), what are crucial parameters for a safer on-line future (Harari, 2020)? What are the dangers behind this (Harari, 2020; Floridi, 2014)? And what is the outlook for the future? Thus, this timely research about digitalisation of remote collaboration, friending, networking, and, of course, romantic dating, combines research about Smart Cities (Kaufmann et al, 2020), with Geert Hofstede's (2001) cultural dimension of 'Uncertainty Avoidance' and Maccoby's (2011) 'Responsible Leadership' with 'online dating platforms' (Markowitz and Hancock (2018) and the success of– Information Communication Technologies (ICT) and the Internet of Things (Leonidou et al, 2020; Santoro et al, 2018). It may also result in the improvement of the use of negotiation tactics as examined by Stefanidis, Banai, Schinzel (2021) and Stefanidis et al. (2016). Moreover, this research offers unexplored ways of collaboration and networking; unexplored, unelected, unlived ways of knowing new people, and letting our imagination flow. More specifically, focus is drawn more on our imagination than on our lying capacity (Schinzel, 2021a, 2021b).

3 SMART CITIES

Smart Cities "are no longer about optimized traffic patterns, parking management, efficient lighting and improvement to public works." (Gartner, 2018). Following Kaufmann et al. (2020), key elements are "increased interconnectivity, real time data exchange, machine learning based on artificial intelligence implying self-controlling production systems. The "four perspectives of DevOps are: 1) Collaboration Culture; 2) Automation; 3) Knowledge (architecture, cloud computing, threat modelling); Sharing knowledge (product and sprint backlogs). Key success factors for the Smart Cities of the future are, following Kaufmann et al. (2020): Connectivity and Networks between administration, Stakeholder and Citizens. They differentiate between different competences required by The Smart City Planner, The chief Digital/IT officer, The Co-operation with external partners, and Training demand. These different competences are: 1) Specific Technical Competences, 2) General technical / Transversal competences, 3) Methodological competences, 4) Social competences, 5) Personal competences, 6) Legal competences, 7) Smart City Planner's competences, 8) Civilizational competences.

Following Bencardino and Greco (2014) "smart city" is generally meant as a city capable of joining "competitiveness" and "sustainability", by integrating different dimensions of development (economic, mobility, environment, people, living and governance).

For Kar et al. (2019), research moves beyond 'Smart Cities', to 'Digital Nations', involving the betterment of diverse social innovation initiatives, interdisciplinary approaches, and intellectual property creation with the citizen being the most important stakeholder. It is especially about innovation, the Internet of Things, Artificial Intelligence, and data driven services. Smart cities require smart citizens who need to be developed in the following domains: 1) digital, 2) social, 3) economic, 4) professional, and 5) personal. Governments need to take initiatives of empowerment in 1) relational, 2) cognitive, 3) behavioural and 4) psychological domains.

Different cultures have cultural differences and need different approaches. This is where Geert Hofstede's research on cultural differences intervenes.

4 SUSTAINABILITY

Traditionally, sustainability has three pillars, namely social, economic, and ecological life (Purvis, Mao and Robinson, 2019). This current research adds a fourth pillar: online life. Sustainability, and especially

sustainability in online services, has become a focus of interest in the last months and years, notably due to its complexity and dynamism, sometimes unpredictability, constituting a powerful stimulator in many social and economic aspects (Fait, Vrontis, Maizza, and Cavallo, 2019). Particularly, and furthermore the current central question is how sustainable are online dating platforms, and in case, how to increase their sustainability? Using technology advancement to increase chances in first dating and finally marriage in research conducted by Izang, Kasali, Ajayi and Adegbenjo (2020) proved them right in their hypothesis about the positive link between the use of social media and sustainable marriage, notably in a world with increased time spent on communication devices and social networks. Especially, and because of the benefits provided by the companies behind the online dating services, the revenues generated, the employment created, these online dating platforms constitute an economic and commercial factor not to be neglected my marketing, communication and management in terms of sustainability and profitability (Jung, Bapna, Ramaprasad, and Umyarov, 2019).

5 RESPONSIBLE LEADERSHIP

Maccoby (2011) defines leadership as follows: "There is only one irrefutable definition of a leader: someone people follow. Therefore, leadership is a relationship between the leader and the led. Unlike management, the leadership relationship cannot be delegated or automated."

This research concentrates on 'responsible leadership,' as a leadership style, that is classified along other leadership styles (Northouse, 2012) such as autocratic leadership, laissez-faire leadership, strategic leadership, responsible leadership, transformational leadership, transactional leadership. Responsible Leadership spans three areas: economic, social/human, and ecological (Financial Times, n.d.). Responsible leadership is defined as being "about making business decisions that, next to the interests of the shareholders, also takes into account all the other stakeholders such as workers, clients, suppliers, the environment, the community and future generations" (The Financial Times, n.d.). Responsible leaders build sustainable relationships with stakeholders to achieve shared objectives, for the common good (Pless, 2007). In this fast-changing world, and following technology used in online dating platforms, combining artificial intelligence and human resource management (Vrontis et al, 2022) has the potential to enhance organizations' recruitment technology and process.

6 HOFSTEDE'S CULTURAL DIMENSION OF 'UNCERTAINTY AVOIDANCE'

In the 1960s, Geert Hofstede defines cultural dimension 'Uncertainty Avoidance' (UAI) as "the degree to which the members of a society feel uncomfortable with uncertainty and ambiguity." The 1960s and the 2020s span 60 years of fast changes and innovation in the Information and communication Technology (ICT), justifying highlighting the following sentence of this definition by Geert Hofstede: "The fundamental issue here is how a society deals with the fact that the future can never be known: should we try to control the future or just let it happen? Countries exhibiting strong UAI maintain rigid codes of belief and behaviour and are intolerant of unorthodox behaviour and ideas. Weak UAI societies maintain a more relaxed attitude in which practice counts more than principles" (Hofstede insights, 2022). Contemporary developments, especially the Internet, online presence, and ICT, allow for particularly different views of what is 'unorthodox behaviour and ideas' in the 2020s compared to the 1960s regarding traditional ways of encounters.

7 ONLINE DATING PLATFORMS

Social innovation can be online dating (Blossfeld and Schmitz, 2011). Traditional encounters for some of us – mainly the young generation - might be online, while for others – mainly the old generation, might be in person. However, in every new encounter, might it be online or in presence, the three following theories apply equally: Impression Management, Truth Management, and False Consensus Effect. Especially lies. Or, more precisely, small lies, let's call them misrepresentations or small deviations of the reality, you might say: fantasy, objects of our dreams, wish-to-be. First, strikingly, called ''impression management' (Markowitz and Hancock, 2018; Ellison et al, 2012, 2006), meaning the beautification of one's self-presentation, where people would deviate slightly in describing their personal attributes such as age, height, weight, professional occupation, personal interests and hobbies, leisure priorities, sexual preferences, alcohol consumption, smoking, and 'personality traits', as well as showing earlier age photos, (Lim, 2021). Second, considering the

before said, 'truth management': where you would ask yourself if the person was telling the truth or not. Consequently, Levine (2014) developed the Truth-Default Theory, suggesting that despite knowing the other person, you can never collect enough information about a person to be able to make the right judgement. Thus, focus is drawn on the deception originated by these lies. Third, there is the 'false consensus effect' (Epley, 2015) which suggests that daters decide if it is acceptable to lie because they surmise that the other person also lies.

Fourth, people might deviate from the reality and be creative when talking about their 'availability.' This is called 'availability management' and involves marital and/or relationship status availability, general time availability, and, more specifically, time for meeting in person availability. Furthermore, some people may underestimate the time any kind of relationship expected of them.

In recent months, focus has been drawn on the 'safety' of users by reducing the 'uncertainty of dating platforms' (Corriero, and Tong, 2016); and by online dating platform requiring users to publish information and share it with all other daters. This information includes identities, background information, criminal records, court records, sex offender status, marital status, lawsuits, and personal reviews. In fact, the strengthening of users' 'safety' has at the same time increased the discussion about a 'complete surveillance' of people. Obviously and consequently, the suggestion for complete traceability of everybody's movements on mobile tracing applications instigated a discussion about the advantages and disadvantages of total surveillance and controllability. Therefore, scholars Yuval Noah Harari (2011, 2015, 2018, 2020) and Luciano Floridi (2011, 2014, 2019, 2020) discuss the risks and opportunities, and the chances and problems of ICT, before the pandemic. Additionally, the ICT discussion does not only include topics like safety, surveillance, and controllability, but also communication, and more specifically 'digital communications,' calling for more professional entrepreneurial education (Papageorgiou et al, 2021).

8 A PROPOSITION

New technologies and computer applications have made the use of such dating and other social and business platforms more acceptable in general, and for Smart Cities in particular. Thus, they are used as a means for improvement of Smart Cities, for the quality of life, where diverse competences are required to improve the quality of life of the citizens. They allow for creativity, imagination, change, and innovation, essentially becoming acceptable means of meeting new people, in private or in business. Hence, the author formulates the following proposition: a fourth pillar is added to the traditional three pillars of sustainability: 1) social life, 2) economic, 3) ecological and 4) online life. Due to the pandemic, new ways of in-person or online dating platforms encounters stimulate and facilitate life in Smart Cities and their development, by enhancing imagination and creativity not only in private life but also in the workplace.

9 METHODS

For the purpose of this research, the author interviewed a total of 15 respondents in semi-structured interviews in January, February of the year 2024, asking them mainly: "How do Online Dating Platforms contribute to Smart Cities?" Interviews were conducted in several languages, English, French, German, Luxembourgish, Italian, Spanish, Portuguese, and translated to English.

In several previous studies, the author had already performed other similar and different research about 'online dating 'platforms', namely, from 2020 to 2022, and in the heat of the coronavirus pandemic, the author investigated 'Love and lies on online dating platforms' (Schinzel, 2021, 2022b) by combining the result of previous studies about 'Responsible Leadership' and 'Uncertainty Avoidance.' Additionally, and to double-check the validity of the proposition, 32 semi-structured interviews were performed in 2022 for the purpose of another previous study.

For the purpose of another study (2021) a total of 242 people were contacted in writing, by telephone or in person via an online dating platform. Out of the 242 participants, first communication contact was in written on the platform, while with 179 this written communication ended then on the platform, 63 were contacted by phone and meetings in person were organized with 18 respondents once, 5 twice, 2 three times and 5 several times. Mainly, the research questions were: Did the coronavirus situation change dating habits? Can you trust people on online dating platforms? Can one really find love there, or is it only lies? Followed by an in-depth literature review on 'Uncertainty Avoidance and coronavirus' and "How to avoid the uncertainty in new encounters on online dating platforms, and not only there?" Replies, in English, German, French, Dutch,

Italian, Luxembourgish, and Spanish, were translated into English and back translated to check for consistency.

Another previous study (2022), consisted of 32 semi-structured interviews and was performed with the objective to validate the findings from the 2021 study, what indeed had been confirmed. The author contacted online acquaintances through face-to-face, WhatsApp and dating platforms, therefore using a convenience sampling. For confidentiality and anonymity reasons, notably not to reveal the true purpose of being on the platform, interviews were chosen over questionnaires.

10 RESULTS

The results from this current research show mainly that 15 out of the 15 respondents believe in the increase in 'happiness in general' through online dating platforms in smart cities. It is believed that happy couples make happy citizens.

	Table 1 How can Online Dating Platforms contribute to Smart Cities?	**N = 15**
1	Increase of 'Happiness in general' of the citizens	15
2	They help the development of the multi-disciplinary Smart City Phenomena	13
3	They represent the development of smart cities intellectual minds	13
4	They improve 'the quality of life in general'	14
5	Citizens embark on an intensive change process	12
6	Citizens unlearn ingrained behavioural patterns	13
7	Citizens internalise an 'Innovative competence set'	13
8	They represent an increase in digital and transferrable skills	12
9	They require more strategic roles of the Smart City Planner / City Chief Digital Officer / City IT Officer / Smart City Administrator	10
10	They represent an intensive change process to determine the gap of competences needed for Smart Cities	12
11	New digital technologies facilitate the Smart City development	15
12	These new digital technologies and especially Online Dating Platforms provide/require newly emerging job profiles	15
13	A specialised software needs to be developed for Smart Cities, such as DevOps.	15
14	This specialised software could include 'online dating'	15

Table 1 How can Online Dating Platforms contribute to Smart Cities?

How can 'Online Dating Platforms' contribute to 'Smart Cities', was answered mainly by the points mentioned in the above table, by 1) an Increase of 'Happiness in general' of the citizens; 2) They help the development of the multi-disciplinary Smart City Phenomena; 3) They represent the development of smart cities intellectual minds; 4) They improve 'the quality of life in general'; 5) Citizens embark on an intensive change process; 6) Citizens unlearn ingrained behavioural patterns; 7) Citizens internalise an 'Innovative competence set'; 8) They represent an increase in digital and transferrable skills; 9) They require more strategic roles of the Smart City Planner / City Chief Digital Officer / City IT Officer / Smart City Administrator; 10) They represent an intensive change process to determine the gap of competences needed for Smart Cities; 11) New digital technologies facilitate the Smart City development; 12) These new digital technologies and especially Online Dating Platforms provide/require newly emerging job profiles; 13) A specialised software needs to be developed for Smart Cities, such as DevOps; and as a consequence of this: 14) This specialised software could include 'online dating'.

"Working towards a common goal that enables the fast flow of planned work into production while achieving world-class stability, reliability, availability, and security" is the definition of DevOps by the DevOps Institute (2019, p.15).

Quotes:

One of the respondents said: "The easiest way to achieve this is if the City Planners include a section 'online dating' into the specialised software for Smart Cities. Directly on the government website, there could be a link to the online dating platform, or the government could develop themselves their own dating platform, free of charge. This would be really innovative. Like the initiative in Luxembourg City to have a 'Sports Pour Tous' – 'Sports for All', that allows everybody to exercise or for free or at a very low price, the

Luxembourg City could also have an 'Online Dating' on their https://www.vdl.lu/fr website. That would be really innovative, new, and people would have a look!"

Another respondent said: "Please have a look at the following websites, we use them in our company for innovation: https://www.dworldvr.com/ This is 'The world's first ever Virtual Economy DWorld, where you experience real life in the METAVERSE. The different worlds are 1) Retail, 2) Tourism, 3) Real Estate, 4) Yachting, 5) Events, 6) Hospitality.

DWorld: "DWorld has recreated the first virtual twin of a country within the metaverse in the world starting from the Principality of Monaco.

We recreate smarter and greener virtual twins of cities worldwide, integrating all the main economic sectors in one single virtual reality platform to start the era of the V-Economy.

Live breathtaking experiences within a dynamic, immersive and interactive environment representing the more sustainable world of tomorrow.

Respondent Nr 3 said: The future of work has these following challenges: 1) Real Estate, 2) Technologies, 3) Transportation, 4) Taxation, 5) Sustainability. You can check this on the website https://www.linkedin.com/company/hrcommunitylu/

Respondent 4 said: "We could call the direct link on the government's website to a dating platform: 'Couples Heureux pour Tous' in English: 'Happy Couples for All' - in accordance with 'Sports pour Tous' or in English 'Sports for All'

Respondent 5 said: "We could have a direct link on the website of 'Sports pour Tous' to online dating, this would be good as participants would already be sporty. There is a 'Cycling Dating' in Luxembourg, but Luxembourg is too small to have enough participants on that online dating platform, we would need to go to Bruxelles Online Cycling Dating" to allow for more people to be there."

The results from the previous studies from the years 2021 and 2022 revealed that respondents lied mainly about the following items (Schinzel, 2021a, 2021b, 2022b): their name, their profile photos (using photos 10 or more years younger), their gender (women who pretend to be men and vice versa), their age, their 'availability', their salary, other characteristics (such as their true motive for being there, alcohol consumption, smoking, sexual preferences, abuse (these traumatizing events in the past often represent a hindrance for future new relationships. Although, in the first place, they would NOT talk about having been abused in the past at all, only later mention it in a second or third encounter), deaths (like abuse, fatalities represent a traumatizing event in the past with often negative impacts on future relationships. If a loving partner has recently passed away, it is difficult to replace him or her entirely), or the loss of one of their children, the loss of their spouse/partner, an injury suffered by one of their children or their spouse/partner, a difficult divorce process from a former spouse, or sexual abuse by a family member.

Here is the representative quote of one of the respondents: "In my opinion, it is NOT about lies. On the contrary, online dating platforms allow for the participants to live some kind of 'second life', where they are living a kind of 'dream', being a different person, a person they would have always liked to be in real life. However, reality is not what they wish it to be. Here they can live their creativity, their fantasies, like a child exploring an unknown world, allowing for new experiences, to live under cover, with a different name, a different photo/image, or a different gender. Their creativity and fantasy are limitless, permitting borderless imagination, where streets are interconnected with secret passages, leading to unknown labyrinths, new people, funny encounters, great discussions, bringing excitement in their otherwise boring lives."

The 2022 study yielded the flowing results:

Out of 32 respondents, 29 confirmed the author's proposition. They stated that with new methods of working, namely working remotely, from home or from elsewhere, the employer can no longer exactly control what employees do during their working hours, and allow for the use of social media, including online dating platforms. These platforms then enable new methods of new encounters, not only romantic relationships, but also friending, networking, and recruiting. However, the main concern is the security of these social media and platforms, requiring firewalls, protection, including the prevention of perversity and crime. There are unknown possibilities of new encounters that remain to be explored paving new ways of creativity (Papaleontiou, 2014) and imagination.

However, the answer options depend on the age and/or on the gender of the respondents. The younger the respondents get, the more they are open about new forms of working, including "online dating platforms" and requiring the "responsible leader" to include them in the work environment, making them "acceptable" for "talent management" strategies in 'human resource management' strategy (Schinzel, 2022a).

Here are representative quotes from five respondents in the 2022 study.

Respondent 1: (female, age 30-40, working in a bank)

"The Coronavirus pandemic has changed the behavior of many people. I think that 'Leadership' and 'Online Dating' are linked nowadays, during and after the pandemic. While, before the outbreak of the pandemic, in the office, it was mainly forbidden to use private Facebook or private other social media. Now everything has changed. Everything is linked, intertwined, we work from home, where we use all our social media channels in parallel. There is no boss to forbid our Facebook or LinkedIn or any other social media attendance, so that 'Online Dating Platforms' see a boom, because we use them during our official 'office' times and not only do we date online during working hours, but we use these online dating platforms not only for romantic dating, but also for friending and for networking.

Nobody wants to go back to the 'old normal', people want to remain in the 'new normal,' continuing to have online contacts all day long, during work hours. The wise leader is aware of these changes and doesn't forbid these contacts during working hours.

People do many things in parallel on their computers, working mainly on several screens in parallel, having several windows open, and chatting in parallel with several people on several channels, all from their kitchen table, or office, or wherever they are. The responsible leader allows these new behaviors and doesn't forbid them. The new generation of young people will be multitasking, they will be 'all-online,' using all their social media channels in parallel with work / school / conferences / etc. The young people will mix all these media to use them for their advantages, for friending, networking, romantic relations, business relations, there will be no more limits or restrictions in their use."

Respondent 2 (female, age 25-35, working in education)

"Nowadays people are digitally connected more than ever. Either for business or private reasons, the usage of dating digital platforms became the normality: every day the first action is to turn on your laptop and meet your colleagues, have meetings; or simply meet your friends, loved ones who are living far away. About love, having a remote relationship with the partner is common. Video calls are received every moment of the day: while cooking, eating. Why not have a virtual lunch/dinner/coffee break together? Psychologists are also telling us that virtual sex is today a normal legitimized practice."

"But, despite humanity's virtual connection increase, people everywhere are experiencing loneliness and uncertainty: they often feel isolated. Social relationships can never be substituted by full digitalization. I think that the feeling of uncertainty could be overcome via high attention and listening while the speaker is talking. Following simple rules either during business or love meetings: put others' devices far away; use the eyes/look to communicate an emotion/feeling; ask the right question and be always curious, open minded creating space for the others to whole express themselves."

Respondent 3: (female, age 30-40, working in a bank)

"Big job changes are to be foreseen. Why is this so? For several reasons. People are working remotely – from far and realize several things. They don't like their jobs, and it is easy to search for a new one, online. So, they quit and find a new one. Or they are close to retirement and prefer to benefit from their free time. Or they have a partner who earns enough money for two. Or they are just fed up with the job. It is important in life to find something that makes you happy.

The next and last subject I want to talk about is the web shopping, where supermarkets have a leading role while designing new concepts for the future, not only to avoid the spread of coronavirus, but also to facilitate shopping while working, remotely or in the office with a large, refrigerated storage places for overnight orders."

Respondent 4: (male, age 50-60, working in education)

"Even though I haven't used online dating platforms for years, being happily married, my opinion referring mainly to my experience with the new online working habits, and meeting platforms such as ZOOM is:

Using new technologies and online platform to communicate becomes a new standard in our day to day lives: at work, to enable and expand work from home; in our private life, to communicate safely with our relatives and keep a social link, whatever the context. All this was made possible with the growing security to join the platforms but also to secure the data. Habits evolved, nevertheless it seems important to me not to forget that behind an avatar or a profile, there is a real person. Why? Because it is easier to create a fake or our "ideal profile of ourselves" in the virtual world. Let's keep reality alive!

If I make a link between the role of a "responsible leader" and "online platforms" the following points are essentials: The need to create or maintain a "community feeling." Team- building exercise, regular meeting, information sharing (not only forwarding a mail). The definition of rules related to the use of online platform or meeting tool: video, document sharing, size of attachments… to limit the "ecological impact." Economically, I would highlight the management of building, infrastructure costs: building location, equipment, such as laptop, headset, and consideration of an indemnity for people who work from home such as an Internet connection, desk, chair, additional screen, and others."

Respondent 5: (male, age 20-30, student)

"I believe that each person needs to be responsible in both. Not all new encounters in business results in deals signed and not all new encounters in online dating platforms would result in a wedding. Artificial Intelligence that can manipulate our choices, in the end the ability to avoid uncertainty in this kind of platform is a kind of manipulation.

Technically speaking, Artificial Intelligence can run a set of tests in order to check if the profile belongs to someone real and the information is accurate, but after that it will always depend on free will of each human if they go ahead or not."

11 DISCUSSION: ONLINE DATING PLATFORMS AND SMART CITIES: THE FOURTH PILLAR OF SUSTAINABILITY: ONLINE LIFE - STRATEGIES FOR SUSTAINABILITY FOR ONLINE DATING PLATFORMS

Over the last ten years research of Smart Cities and sustainability has mainly focused on three pillars (Purvis, Mao and Robinson, 2019): a) social life, b) economy and c) environment (Thompson, 2017). This current research, however, adds a fourth pillar to the above mentioned three: d) Online life. On the one hand, this research follows on research conducted by Izang et al. (2016) on 'sustainable marriage' and focuses on 'Sustainability on Online Dating Platforms'. On the other hand, it generalizes the investigation to include 'creativity and imagination' (Papaleontiou et al. (2014) and 'digital communication' (Papageorgiou et al., 2021). Especially the 'community effect', generated by online dating platforms, is of interest for the community sustainability and the profitability of the online dating platforms (Jung et al., 2017). Notably, and this is the conclusion of Mouratidis & Papagiannakis (2021), virtual mobility increases ecological sustainability by reducing traffic, especially by reducing and changing transportation, leading to more sustainable cities and society in general. The strategy for the future is to become more sustainable by being online, the fourth pillar of sustainability – social life, economy, ecology, online life.

12 CONCLUSION

Online dating platforms could be an integral part of Smart Citie's Software. Already by now, Online dating platforms are not only used for romantic relationships, but also for friending and networking, for collaborating and working together, negotiating, and even recruiting new staff, as shown by BBC (2021). These have a great potential to progress and develop in the future in Smart Cities. This is how stability, reliability, availability and security are enhanced. Parallel online activities, such as networking, friending, collaborating, negotiation, communication, working, and relaxing stimulate imagination and creativity. Unlimited use of online services, in all aspects of life, may create new concepts that may lead to a complete new concept of Smart Cities without boundaries. It may establish new ways of human activities such as shopping, working, transport – street, rail, air, sea, - friending, contacting, recruiting, negotiation, collaborating (Mouratidis and Papagiannakis, 2021). Future research may investigate the relationships among Online Dating Platforms, Artificial Intelligence and information communication technologies, and develop new domains, such as negotiation (Stefanidis et al. (2016).

Despite some lies on online dating platforms, creativity, argue Papaleontiou et al (2014), increases the possibility to create new knowledge and ideas, where everybody and everything is connected, while using all social media in parallel for all kinds of purposes. Artificial Intelligence and ICT are used thanks to ever growing creativity and imagination, outside-of-the-box-thinking, while Geert Hofstede's (Hofstede insights, 2022) cultural dimension 'Uncertainty Avoidance' was propagated in the 1960s, other ways of thinking are acceptable in the early 2020s. A fourth pillar is added to sustainability: social life, economy, environment, and online life, with user friendly connected infrastructure (Albino et al., 2015).

The combination of 'Online Dating Platforms' with 'Smart Cities' is innovative. The creation of a direct link on the website of the government to an online dating platform would be a 'nice to have' solution for the future of smart cities. Or the direct link from a sports association to online dating platform.

13 FUTURE RESEARCH

Future research could focus on the implementation of this direct link on the government website to an online dating platform and evaluate the results. Using more statistical methods by using big data and a bigger number of respondents would help coming up with better statistics and correlations.

Future research could also be a cultural comparison among different nations in Smart Cities – in Digital Nations - following Geert Hofstede.

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🏆 *reviewed paper*

Smart Culture: Digitisation Strategies of two Museums in Tuscany

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1 ABSTRACT

The importance of digitalisation in the cultural industry has been recently enlightened by various researchers (Giannini and Bowen, 2019; Ahmed et al., 2020; Fanea-Ivanovici and Pană, 2020). The purpose of this study is to analyse the impact of smart technologies in the cultural industry, which plays an important role for many urban areas in Italy. We decided to perform a qualitative case study research approach (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Yin, 2003) because of the exploratory nature of the research question and the novelty of the phenomenon. Therefore, we focused our analysis on two case studies, specifically two museums based in Tuscany. Thus, we wanted to investigate the impact of digitalization on cultural marketing, which is here considered as the impact on communication strategies and interaction with customers and users, while also including the structure that supports and precedes the final communication and interaction. We choose the museums on the basis of their characteristics and geographical location, in order to be able to analyse two different case studies. As mentioned in the existing literature (Agostino and Costantini, 2021), one of the outcomes of this research concerns the lack of appropriately trained personnel on the topics of technological innovation and marketing 4.0. It also emerged that the level of digitalisation achieved is influenced by the peculiar characteristics of each museum and their geographical location. In one case, given its specific nature as a museum showing something no more existing, the installation and use of immersive, virtual and augmented reality technologies within the museum was preeminent. In the second case study, concerning installations or works of art, a more traditional approach was preferred. Furthermore, it was noteworthy to stress that both museums, based in areas less subject to mass tourism, also targeting more a niche rather than general segments, strengthened their digital marketing strategies, thanks to the use of new technologies. This, to reach their maximum potential awareness among the public, thanks to the use of communication methods that would bring non-expert users or non-enthusiast closer to their realities. Hence, the level of digitalisation is significantly influenced by its geographical location and the type of tourism that characterises it, and this influences the museum towards the adoption of those technologies able to better satisfy visitors and to create a valuable experience for them. In any case, all the interviewees agree in saying that technology, if used efficiently, could bring great benefits in terms of improved customer engagement, efficient use of data for adapting the strategies and for creating customer value. Furthermore, technologies can lead to economic sustainability by reducing costs and increasing revenues. However, this is possible only if specialised personnel are hired and trained to support and advise visitors.

Keywords: Smart City, Governance, Cloud, Security, Compliance

2 INTRODUCTION

The characteristic of 'transformability' (Bauer et al., 2015), is nowadays essential for keeping up with the changes introduced in the marketing world by 4.0 technologies. In this context, Nosalska and Mazurek, (2020), suggest so-called 'design principles' that provide useful tools for constructing a functional and effective marketing strategy, and these are: interconnection, information transparency, technical support and decentralised decisions.

In analysing the impact that 4.0 technologies are having on marketing and consequently on the strategic choices related to it, it is necessary to look at these changes as strategic goals to which to aspire (Ungerman and Dedkovà, 2019), without, however, neglecting the issue of flexibility, which is a key element in overcoming the obstacles that these changes bring with them. The literature shows that the greatest difficulties encountered by small and medium-sized enterprises are mainly related to data protection, maintaining a good reputation and keeping up with new customer needs, which in this context will have to be aligned with the overall of distributive and promotional processes of the brand/service (Peter and Della Vecchia, 2020).

The Internet of Things has made it possible to create a new dimension, characterised by an advanced interconnection which today becomes the distinct element of marketing 4.0, which transforms marketing 3.0 and the related technologies linked to Web 3.0, into an evolved one. From these considerations, one of the four pillars of marketing 4.0 already emerged, namely brand interaction, which highlights the increase in customer engagement in the product/service design phase itself (Dash, Kieferand Paul, 2021). Brand interaction is accompanied by other factors such as brand identity, brand image and brand integrity.

What has just been observed is highlighted again in the analysis of the five key principles of marketing in the context of industry 4.0, which according to what emerged from the literature are: cooperation, conversation, co-creation, cognitivity and connectivity, which is considered the principle that most characterises the application of marketing 4.0, as it unites all new technologies and is fundamental in making the best use of them (Nosalska and Mazurek, 2020).

From the literature it emerged that some of the trends that characterise marketing 4.0 are digital marketing, which uses digital communication technologies; internet marketing, relationship marketing, which is based on building lasting relationships with the customer and mobile marketing, which bases its strategies on the use of ad hoc adverts for mobile devices such as mobile phones or tablets (Ungerman and Dedkovà, 2019).

3 THEORETICAL BACKGROUND

3.1 Marketing 4.0: a boost for companies' competitiveness

The adoption of technological innovations in the field of marketing have allowed small and medium-sized businesses to significantly improve, despite the difficulties encountered in adapting their business model to changes, the relationship with the customer in terms of connection but also of interaction and participation, also making the market orientation more evident and recognisable (Alford and Page, 2015).

Gupta et al., (2016), in their study, illustrate the presence of a positive correlation between the use of marketing 4.0 technologies and an increase in competitiveness for companies, and vice versa, making the use of marketing 4.0 innovations, an opportunity for a potential common benefit between manager and customer.

An increase in competitiveness for companies given by the use of marketing 4.0 technologies is related to the management of Big Data, which has increased significantly with the arrival of industry 4.0. Thanks to new technologies it is possible to use the management of this data, which will be effective and efficient, as a means to increase the quality of the business, thus increasing its competitiveness (Ungerman, Dědková and Gurinova, 2018).

Ungerman and Dedkova, (2019), explain how there are two perspectives from which it is possible to observe and therefore quantify the impact that the adoption of 4.0 technologies actually has on businesses: a purely economic point of view, which is based on the monitoring of accounting indicators (ROA , ROI) and on the control of sales volume, revenue growth and market share, from which marketing performance can be deduced; and from a non-economic point of view, observing creation of new business models; creation ad transition towards new jobs; differentiated workflows; new communication systems; decrease of occupational injury risk; increase in public relations and an increase in competitiveness which are all consequences of the potential opportunities that the use of 4.0 technologies brings to business.

Furthermore, thanks to the intrinsic characteristics of new technologies, it is possible to approach marketing 4.0 by observing it as a tool which, in addition to producing feedback, allows the company flexibility and facilitates understanding of the business (Vassileva, 2017).

3.2 Digitisation in cultural marketing

With the introduction of the new Marketing 4.0 technologies, there has been an implementation of targeted interventions by entrepreneurs of large, medium and small enterprises, aimed at implementing the transition to more digitalised marketing and communication strategies than before, which enable, facilitate and induce more interaction with customers (Lacárcel and Huete, 2023).

Following the focus of the International Council of Museums on the topic of digital transformation in the cultural sphere (Liao, Zhao and Sun, 2020), it was concretely confirmed, even within the cultural industry, what had been anticipated earlier by Amitrano, Gargiulo and Bifulco, (2018), namely that in this climate of

globalisation and technological innovation, the value that marketing offers today is predominantly linked to the interaction it manages to obtain as output from the customer.

Although the cultural heritage context is characterised by the symbolic values that the works constituting it carry, it is nevertheless possible to identify three actors within this market: the author, the user and the artistic and cultural organisation (Colbert and St-James, 2014). In the context of the fourth industrial revolution, these three actors have revolutionised their dynamics of interaction within the cultural market by modifying, both from the perspective of the artist and from that of the organisation, the very conception, perception and management of art, which, precisely because of the intrinsic and symbolic value it possesses, has created various divergences and uncertainties (Bertacchini and Morando, 2013).

This analysis aims to identify the technologies used in marketing 4.0 within a cultural context, evaluating the advantages, obstacles and the degree of digitalisation achieved to date. Generally speaking, marketing 4.0 has pushed public and/or private investments towards the development of effective digital communication strategies to generate involvement in the target audience. As Lacárcel and Huete (2023) explain, this has also had a significant impact on the job market, increasing the demand for highly qualified professionals in the sector, capable of creating valuable content, managing online communities and identifying new sales opportunities.

There are different models of application of new marketing technologies in the cultural context, focusing in this study on museums and art foundations. The first model considered is online access to collections, which can improve the usability and accessibility of works if implemented effectively on museum websites. Initially conceived as mere information tools, museum websites now have the potential to become true extensions of the museums themselves, offering virtual experiences that enrich value for visitors (Bertacchini and Morando, 2013). It is increasingly important to encourage an active experience on the part of the visitor, encouraging him to become a promoter of the museum through feedback and digital interactions on social networks or via mobile apps.

Among the technologies potentially useful for this purpose we find augmented virtual reality, tablets and mobile devices physically installed inside museums or art foundations. These tools allow visitors to interact with works of art, test their knowledge through games or quizzes and enjoy multimedia content such as 3D cinema (Izzo et al., 2023). Social media play a fundamental role in cultural marketing 4.0, allowing an in-depth analysis of customer needs and facilitating the co-production of services, the creation of value and the establishment of relationships with customers (Amitrano, Gargiulo and Bifulco, 2018).

The literature analysis suggests that innovative communication strategies and channels used to actively engage visitors can be divided into two models: “inside” and “outside”. The “inside” model includes technologies installed within the museum space that enrich the experience and have educational and archival potential, while the “outside” model includes technologies aimed at promoting the museum outside its physical space, increasing visitor awareness and monitoring their engagement (Leoni and Cristofaro, 2021).

Focusing this analysis on the context of Italian museums, according to the study conducted by Agostino and Costantini (2021), it is highlighted that digitalisation in these contexts is lacking in terms of preparation and updating, lack of qualified personnel within the teams, and a lack of long-term vision regarding digital transformation, with a general lack of attention towards the topic. This underlines the importance of transversally evaluating the impacts of digital transformation and conducting comparative analyses to promote knowledge and improvement. Furthermore, the Italian situation seems to be progressing more slowly than the rest of Europe, as indicated by Izzo et al. (2023).

However, as highlighted by Leoni and Cristofaro (2021) and Bertacchini and Morando (2013), the adoption of innovative technologies linked to the fourth industrial revolution, and therefore to marketing 4.0, presents challenges and controversial issues in the cultural context. These challenges may arise from compromising financial and economic sustainability, as well as maintaining the authority and institutionality of the museum in a digital context where access to works of art is more liberalised. There is also discussion among experts (e.g. museum directors, managers and curators) about the risk that the adoption of these technologies could lead to co-destruction of value rather than co-creation for museums. This is particularly evident, especially when considering the various challenges that may arise with the implementation of 4.0 technologies. These challenges encompass issues such as the expenses associated with deploying, embracing, and sustaining such technologies, along with the manifold adverse impacts these technologies may have on visitor satisfaction. In

regard to the latter, numerous studies underscore the peril posed by the sensationalization, trivialization, and commercialization of museum offerings. Additionally, visitors to museums may perceive technological tools as hindrances in certain instances, as they may be ineffectively deployed within the museum environment, serve as distractions or isolators, or curtail opportunities for human interaction and communication. Furthermore, a research thread delves into how technologies could exacerbate the digital divide. Indeed, generational disparities influence visitors' expectations regarding technology during museum visits, as well as their proficiency in utilising the available technological resources effectively. Given the potential adverse repercussions outlined above, museums must engage in critical introspection concerning technology adoption and acknowledge that there is no singular optimal approach, but rather a multitude of optimal pathways contingent upon the museum's specific typology (Leoni and Cristofaro, 2021).

Despite this, the adoption of innovative technologies represents a unique opportunity for museums and art foundations in terms of creating value for the customer, through the implementation of interaction, as highlighted by Amitrano, Gargiulo and Bifulco (2018), and from the point of view of the strategic possibility of strengthening the importance and knowledge of culture and heritage (Izzo et al., 2023).

As highlighted in the study by Wereda and Woźniak (2019), the main challenges of marketing 4.0 in the cultural industry include building effective customer relationships and developing communication strategies adapted to customer 4.0 needs. This new type of customer requires new interaction strategies and a user-oriented approach from the awareness phase to the use of the services offered by the museum. The use of digital communication channels can improve the quality of the process of establishing a lasting relationship with the 4.0 customer and support the marketer in information management and decision-making.

4 METHODOLOGY

Considering the exploratory nature of the research, we decided to use a qualitative approach (Eisenhardt, 1989; Eisenhardt and Graebner, 2007) based on case studies (Yin, 2003).

The study was conducted by carrying out two in-depth interviews with managers of the museums, focusing our attention on marketing and customers' (i.e. visitors) interactions based on technological solutions adopted by the museums, since it represents a fundamental aspect for the creation of customer value in the smart era (Wereda and Woźniak, 2019). The cases to be analysed were carefully chosen, based on the characteristics of the two structures being analysed. Although both are located in Tuscany, an Italian region with a strong tourist vocation, and are dimensionally comparable, they each present interesting peculiarities in the field of digitalisation and marketing that are worth analysing and comparing.

We collected data through several sources. In addition to an initial desk analysis to identify the most significant subjects for our research, we carried out two interviews. This primary data was collected between July and September 2023. For each case analysed, an interview lasting approximately an hour and a half was carried out following a pattern of semi-structured questions in order to carry out an in-depth analysis of the topics of interest (Yin, 2003). The topics that are part of the semi-structured guide are the following: general questions on the structure, on the business model adopted and on the project, specific questions on the marketing strategy, as well as on the idea and its development. The interviewees were then encouraged to talk about digitalisation in marketing, the use of new technologies and their possible applications. All interviews were recorded and then carefully transcribed.

In addition to primary information, secondary data was also acquired, such as archive data, financial statements and other information available to the public and online (Gibbert et al., 2008). By doing so it was possible to triangulate the data to achieve an adequate level of internal validity (Yin, 2003; Gibbert et al., 2008).

5 CASE STUDIES

With a view to facilitating the analysis of the case studies, below are some data that allow an observation of the context where the two Museums are located from a quantitative and qualitative point of view. That is, data will be reported relating to the intensity and representative characteristics of the tourist phenomenon present in the areas of Castelnuovo dei Sabbioni (municipality of Cavriglia, province of Arezzo) and in the Chianti Senese (considering the entire territorial area of Chianti in the province of Siena).

As regards the tourism phenomenon present in the territory of the Municipality of Cavriglia, from the observations carried out by the “Visit Valdarno” project and then as reported in the 2022 economic analysis carried out by IRPET, in the Municipality of Cavriglia during the year 2022 there was the presence of 100,750 tourists, of which approximately 59% were foreigners mainly in the summer period. The tourism characteristic of the place is tourism aimed mainly at exploring the surrounding landscapes. Regarding the territorial area of the Chianti Senese, what emerged from a study carried out in 2019 by the Florence Tourism Study Center and published on the General website of the Chianti Service, throughout the pre-pandemic decade 2009-2019, is the presence of 78% of foreign tourists. The characteristic tourism of these areas is characterised by visitors in search of peace and tranquillity, who, fleeing from the big cities, seek the beauty of the landscape.

5.1 Museo Mine

Mine Museum is located in Castelnuovo dei Sabbioni, which is a village in the province of Arezzo in Tuscany. We had the opportunity to interview the scientific director.

The Mine Museum is situated within the picturesque village of Castelnuovo dei Sabbioni, nestled in the Valdarno region of Tuscany, renowned for the passage of the Arno river amidst its settlements. Castelnuovo dei Sabbioni and its surrounding environs, including Santa Barbara, were once vibrant locales characterised by the extraction of lignite from mines, prompting the establishment of a purpose-built village to accommodate miners and their families. In the late 1930s and early 1940s, Leonardo Lusanna orchestrated a project pertaining to the briquette factory in Castelnuovo dei Sabbioni, aimed at harnessing lignite briquettes for energy production. The factory, erected in the early 20th century alongside a power plant, sought to optimise the utilisation of lignite by transforming it into compact briquettes for commercial purposes, thereby addressing Italy's fuel scarcity predicament. Historically, the inferior quality of lignite compared to foreign coals had impeded its market viability, leading to the closure of numerous mines. However, the advent of lignite briquette production offered a pragmatic solution, owing to the favourable attributes of these briquettes, namely their low moisture content, minimal ash residue, and higher calorific value, rendering them suitable for both domestic and industrial applications. The manufacturing process encompassed various stages, including lignite fragmentation, drying, compression into briquettes, and the utilisation of a thermal power plant to generate requisite steam and electricity for processing. In 1940, Leonardo Lusanna elucidated the project's intricacies in a technical report, delineating the patented design of the factory, comprising a thermal power plant and a dedicated briquette manufacturing facility. Regrettably, four years later, the advancement of German troops precipitated the destruction of the mining plant and power station in Castelnuovo dei Sabbioni, marking a poignant conclusion to this chapter of industrial history.

Historically, Mine Museum was born with the perspective to be a scholastic museum, whose materials were supplied by a scholastic organisation belonging to the territory which, starting from 1970, guided by the need to pass on the history of the place, had collected and handed over all the assets of the museum. In the years that followed, the museum evolved into a true historical documentation centre, a kind of archive for the Castelnuovo dei Sabbioni community. The plan to open a museum, however, was born between 2007 and 2009, and then materialised in 2012, when the Mine Museum that we know today was officially opened. Museo Mine was therefore born as a historical-anthropological museum, already innovative at the time of its opening and especially in the territory of the municipality of Cavriglia, which already made it an interactive place when it was set up. The initial idea behind the Museo Mine project is based on a chronological order, a dimension in which different types of media act synergistically, starting with the physical and ending with the use of files and multimedia devices "used with the aim of creating an immersive environment even without real immersive technology".

The majority target segment of the Mine museum is undoubtedly represented by the population of Castelnuovo dei Sabbioni and neighbouring towns. The reason for this lies in the very nature of the museum "proving to be self-representative for the community", reconstructing a collective imaginary through the use of historical pieces, testimonials and documents that the local community itself had decided to preserve and share with the Museum. Furthermore, a second reason, which justifies the above, is given by the dimensions of the Museum itself, whose restricted area appears to be an obstacle to a more intense tourist phenomenon characterised by mass visits and therefore limits access. Continuing the analysis, it emerged from the

interview that another target segment is represented by foreign and/or Italian visitors, who, passionate about the theme of mining, seem to appreciate the uniqueness of what is shown in the museum, in this context the Mine museum also boasts some recognition at a European level, being part of some circuits specialised in the mining sector, thus also implementing the promotion of the museum itself abroad. However, it remains a niche area, therefore not very well known and visited compared to other museums. This difficulty also emerged from the fact that Museo Mine is the only mining museum in Italy without mines to visit. Another target segment for the museum is represented by the local schools and surrounding areas. The children who are taken on a trip to the mine museum are offered activities that encourage and invite participants to reflect on the issues dear to the museum, first of all energy sustainability, but also the value of sharing and memory. These activities, proposed through games or in other forms based on the age of the participants, appear to be appreciated.

The scientific director explains how for the museum the digitisation process, contextualised in the marketing field, has made it possible to analyse and compare the visitor's perception, accepting the need for careful observation of the visitor's needs and feedback. Digital marketing in this context is mostly used through the creation and sharing of videos and films. In any case, other technologies are also used within the museum itself, such as QR codes which, being directly connected to the museum's YouTube channel, are very simple and usable for both adults and children.

Within the application it is possible to find a guided tour route and the development of a film production in LIS is underway.

From the interview carried out, it emerged that the evidence of a trend of improvement in terms of customer value and engagement emerged following the introduction of the use of new technologies, used while always respecting the values of the museum such as sustainability over time aimed at avoiding the onset of interoperability problems between different software or technologies.

The museum's major partners are municipal and regional bodies and associations that are part of the European circuit interested in the mining issue. It is interesting to notice that an important portion of the partners is composed of private citizens who, since the opening of the museum, have been donating the finds that characterise the museum.

Museo Mine currently has four different social channels such as Facebook, Instagram, YouTube and a website, recently renewed thanks to a collaboration with a company based in Salerno. Going into detail it is possible to observe how a certain communication strategy was chosen for the website, using it as an information collection point for the visitor, who by opening it can discover basic information such as opening hours and days, where the Museum is located or a small mention of its history or subscribe to the newsletter to stay updated on proposed events or news. From the site it is also possible to access various spaces, including a multimedia section which acts as an archive of projects and another which refers to a previous website of the Museum which displays a very vast selection of photos and documents for the visitor, with the aim of share the memory of the local community as much as possible.

The Mine Museum website was voluntarily designed with the priority of obtaining very simple management in order to be more usable and always easily modifiable.

Analysing instead the three social media channels used by the museum, such as Facebook, Instagram and YouTube, it emerged that the most used as a channel of interaction with the visitor is Facebook, which represents for the museum, but also for the user, a sort of stock market diary always updated on news and which allows a real possibility of dialogue thanks to the numerous comments and interactions. The strategy that is chosen for the use of Instagram sees it as a well-curated and elegant photographic archive that tells the story and curiosities that revolve around the Mine Museum.

However, considering the strong heterogeneity of the public between the two social platforms, lately the possibility of adopting a more homogeneous and synergistic communication strategy in the two channels is being considered, with the aim of reaching and involving as many people as possible.

Given that Museo Mine is also accredited in the museum system of Valdarno (province of Arezzo, Tuscany), it was involved and participated in a project aimed at the implementation and improvement of digital communication in the cultural industry and in particular museums, leading to the development of a virtual tour of the museum, as well as the sponsorship of the latter through the Ambassadors, i.e. young people from

the area, who told its story on Tik Tok. Other local platforms have also decided to take part in the digital narration of Museo Mine, such as the visitvaldarno website and the regional systems that are developing promotional programs that focus precisely on culture contextualised at an industrial level.

Another digital channel used by the Museum is that of a podcast, carried out by some local kids, which can also be accessed via the museum's Instagram channel.

Furthermore, with the desire for a conscious use of technology, aimed primarily at narration and dissemination, all the events held at the museum are recorded and published on the various social profiles so as to extend participation to those who were unable to be physically present and given the great attention to the topic, the museum is thinking of activating chat boxes to allow greater interaction.

The Mine Museum is also accredited for the national museum system.

Finally, touching on the topic of sustainability, what emerged from the interview is a lack of use of new technologies in the field of environmental sustainability, a consequence of a lack of funding in this sector. On the contrary, however, as demonstrated by the development of the application in LIS and the presence of various technologies that can be used by all people with hearing or visual disabilities, the value of social sustainability and inclusiveness is supported.

5.2 Chianti Sculpture Park

The interview with Chianti Sculpture Park took place in two separate moments, in an initial phase with the owner of the park, Piero Giadrossi, while we also interviewed Chiara Bozzi, who plays a fundamental role within the park, including marketing management.

The owner Piero Giadrossi explained in the interview the history of the park.

Initially, he and his wife initially owned an agritourism in Chianti which was called La Fornace having previously been a real furnace, linked to the Superintendency. On the other side of the road there was an oak and holm oak forest of about 14 hectares. They decided to buy it to make sure that no one would build houses in that area. In this forest there was an animal enclosure that occupied about half the space. The animals were later sold and thus found themselves with a fenced and usable area.

As Piero Giadrossi writes in his book “From Trieste to Chianti” (Giadrossi, 2021), while in Africa, they used to visit the Kirstenbosch botanical gardens and once organised an exhibition of Shona sculptors who came from the state of Zimbabwe, north of South Africa. Seeing this exhibition of mostly black marble sculptures that looked great against the green background of the gardens, it occurred to Piero Giadrossi that he could do something similar on his own property in Chianti. But the idea was not enough and so by delving into the topic he discovered that in the United States, in Hamilton (New Jersey) there was “Grounds for Sculpture” (https://www.groundsforsculpture.org/), a non-profit organisation founded in 1992 which in addition to make beautiful exhibitions every year organised a course for those interested in Sculpture Parks. Therefore, as he returned to Italy, he asked a surveyor from Gaiole to create a ring route (very irregular) in the former enclosure. Hence, he started thinking about a park with main characteristics guiding the choice of sculptors being two: their great internationality and the variety of materials used. Initially he organised two meetings at his house with some experts in the sector but without obtaining a decisive contribution.

In the end it emerged that the best and most concrete thing was to invite the sculptor into the woods, ask him to choose a place and then make a proposal as integrated as possible to the chosen place. In fact, the integration between contemporary art and nature is the third element that characterises the Chianti Sculpture Park. In any case, after three years of intense work the inauguration of the park took place in May 2003.

At the moment the Park hosts artists from 19 countries on 5 continents, many are well known in their countries of origin.

As for the materials, the variety is great: 5 works are made of glass (a material rarely seen in parks), then we have iron rod, volcanic lava, sounding steel cubes, and of course marbles of different colours and travertine.

Furthermore, in 2012 the Amphitheatre was added using a natural slope of the land.

Also, from the marketing and managerial perspective some interesting aspects emerged. This was mainly possible thanks to the interview with Chiara Bozzi.

It emerged that the most important target segment at the time of the inauguration and opening of the park was made up of foreign tourists. This fact is explained in the very nature of the tourism present at the time, but also today, in the Chianti area, a tourism characterised mainly by French, German, Spanish and Dutch tourists. However, despite these data, following the pandemic there were slight variations in the target segments of prevalence, and in fact it is assumed that the lockdown stimulated the local population to take more trips out of town in the areas surrounding their homes or in general in the regions nearby, today in fact another important segment for the park is made up of Italian tourists coming from Tuscany or other regions. In this context it is equally important to underline how the massive use of social networks by the park due to the pandemic has also seen the increase in foreign tourists. A target segment that has remained unchanged and constant since the opening of the park is that of contemporary art enthusiasts.

With a view to increasing the loyalty and involvement of tourists and visitors to the area, the park has recently started to offer events and concerts, also taking advantage of the presence of the amphitheatre. These activities were designed with the aim of creating greater involvement in the visitor, transforming the park into a place not only of art and culture but also of sharing, thus making it a potential point of reference. The difficulty that the park encounters in this area is certainly given by the fact that in Italy contemporary art is still an attraction considered niche.

Another initiative created to also involve the local community is that of the B.A.C. project. i.e. Pievasciata Borgo d'Arte Contemporanea which is a recent initiative which has involved the contribution of institutions and private individuals, i.e. the owners of the land to whom an "integrated" sculpture is proposed, this initiative has contributed to creating a tourist flow in an area very little known in Chianti and has also helped to recover some disused or abandoned areas of the village.

The use of technology has always played a fundamental role in the communication of the Chianti Sculpture Park. The first approach to technology used as a means of communication and interaction with users occurred with the creation of the park's website, which occurred shortly after the opening. An initial online presence of the park immediately allowed greater awareness also to international tourists visiting Italy. Furthermore, as mentioned previously, the park immediately used another channel of digital excommunication, which is that of social networks, developing and updating its strategy trying to keep up with the times. Instagram functions perfectly as a promotional tool and therefore its use has been made a key element of the park's marketing strategy. This was done through the creation of reels by some influencers visiting the park, which significantly increased visits, also expanding the phenomenon to TikTok, registering a large audience of both young and adult viewers. The Instagram profile is normally updated three times a week with the publication of photos and videos, and daily through stories which allow great interaction with the public. Given the increasingly evident needs of having a good online presence, the park is thinking of investing in staff training aimed at professional data monitoring and in possible ways of promoting the online park.

As regards the use of technology inside the park, Bozzi explained how in 2014 an ad hoc app was created to be used as a self-guide. This application, thanks to a loan won in 2022, was recently updated, making it available in four languages and adaptable to all devices. The application appears to be greatly appreciated by visitors to the park who often express positive opinions and appreciate its ease of use but above all they consider it a very useful tool for fully enjoying the experience of the visit, as thanks to the simple self-guiding, the contemporary art is made understandable even to the less experienced, increasing the value and quality of the visit itself.

The park is also often sponsored by blogs and businesses in the area that suggest the Chianti Sculpture Park in their guides via the website link. The park is affiliated with the FAI and touring club, who include it in their online guides, it has also been mentioned in publications in National Geographic, Corriere and recently by the La7 television channel and TG2, thus managing to reach a wider audience. Bozzi explained that the newsletter is structured through the use of two lists, the first being that of the "aficionados", to whom a newsletter is most frequently sent containing information relating to events, concerts and activities organised by the park, and a another, which updates visitors every two months with more generical information. Social networks are very valuable in terms of interactions and are used by many visitors or potential visitors to ask for information or curiosity. The park also constantly records statistics on the origin of visitors and the way in which visitors learned about the park, so as to be able to consciously refine promotion and communication

strategies. The offline communication and distribution component still remains of fundamental importance for the park, even if decreasing, especially given its geographical position and the type of tourism present in the area, as underlined by Bozzi in fact, in the specific case of the sculpture park of Chianti "online cannot exclude offline", in fact the use of brochures is still present, left above all inside the accommodation facilities in the area, to also reach tourists who are less inclined to use technology or who prefer to explore the area without creating plans by searching online.

Chianti Sculpture Park today creates great value for the visitor, for the tourist, for the families and for the citizens of the local communities, who always greatly appreciate the experience of visiting the park, as it offers a harmonious and stimulating fusion between art and nature, which encourages visitor participation and creativity thanks to the presence of works with which it is possible to create a real interaction, touching them or exploring them internally, fully immersing oneself in the visit experience. Precisely due to its characteristics and its naturalistic environment, Chianti Sculpture Park offers a particular and different experience compared to that of a normal museum or artistic foundation, and has succeeded over the years, also thanks to the use of facilitation tools such as the app, to reach even the least expert in artistic terms.

Chianti Sculpture Park recognizes the values of sustainability, especially environmental and social, as fundamental values present right from the start in the conception of the idea of the park, immersed in a wonderful naturalistic environment, which the park wishes to make known with its art and nature project and educate to respect, love and care for nature, offering "an essential link between art and nature" as Bozzi explained during the interview. Therefore, in compliance with these values, the park has some bans such as smoking inside the park, and since January 2023 the park has joined the "carbon neutral" Sienese alliance and organises various events in collaboration with them. Technology was used in this context in order to reduce waste, especially paper and plastic which has been significantly reduced, and for energy efficiency. The value of social sustainability is carried forward by the park through various activities, the most striking is that of the Borgo D'arte di Pievasciata as it is "a project by the community for the community", the park also engages in cultural dissemination activities and social themes also represented in the works of the park themselves, in this context a lot of attention is also paid to inclusiveness, organising guided tours for people with visual disabilities, the park is also affiliated with Siena Sociale, to which it had made free tickets available for volunteers, encouraging social value through community and sharing.

6 DISCUSSION

In order to reach our conclusions, we decided to conduct the following analysis from a comparative and thus cross-sectional perspective in order to provide as broad a view of the subject as possible.

With regard to the Mines Museum, what emerges from the interview is a picture of a museum that fits into a very particular niche of interest, that of mining routes and history, which, however, is not tangibly witnessed within the museum, since mines no longer exist there, a factor that significantly influences the characteristics of the majority target segments and gives rise to the museum's need to use a certain approach towards the adoption of new technologies, which is reflected in the case of Museo Mine with the use and installation of many virtual and augmented reality devices inside the museum, which guarantee the user an immersive visiting experience. On the other hand, however, analysing the Chianti Sculpture Park interview, what emerges is a reality that approaches, from this point of view, in a more traditional way to the use of new technologies, since the main attraction of park consists precisely in the observation and interaction that the user can have with the sculptures that are already present and tangible within the park. However, other needs that arise in the context of the Chianti Sculpture Park are highlighted, which have led to the adoption of new technologies in other areas, such as training and education, in fact, as emerged from the interview, the development and use of a application for mobile devices was of fundamental importance in educating the visitor to understand the contemporary art sculptures present along the route of the visit, which can often be difficult to understand for those less expert in the subject. This approach used by Chianti Sculpture Park is also confirmed by the choice of its marketing and digital communication strategies with users, which are channelled through the use of social networks, especially Instagram, with the aim of bringing potential visitors closer to a reality which in Italy is still niche and often misunderstood, like that of contemporary art, with the use of promotional strategies such as influencer marketing and the publication of reels and illustrative posts, but which at the same time seeks to build a relationship of trust and interaction with those who already know the park, making them participate in everyday moments using tools such as Instagram

stories. As regards the communication strategy adopted by Museo Mine, it emerges that this is mainly influenced by the type of target to which it refers, and therefore it was chosen to use four communication strategies diversified based on the audience present on the Museum's various social channels, such as Facebook and Instagram, keeping the website as a reference point from an information point of view and using social channels to generate greater interaction. It is possible to find confirmation of what has just been described in the lower part of Fig. 1, which shows the interpretative framework.

From the above is highlighted a different conception and approach to the use of new technologies: in the first case, that of Museo Mine, we observe a small town reality that approaches new technologies considering them mainly as a facilitator of activities and management of the same, which at the same time allow the museum to create great value for the visitor by offering unique experiences. On the other hand, however, we observe a reality that deals with a niche interest, and which therefore, as anticipated, approaches and defines the method of adopting new technologies as an educational and promotional tool.

In general, considering the information reported above, in both cases a lack of trained personnel emerges in terms of digital transition in the cultural field, which confirms what was anticipated in the literature in the study by Agostino and Costantini (2021). This difficulty is also found in monitoring the data obtained from interactions with the social channels of the two museums and in this context both highlight the need to invest more in this area.

Furthermore, analysing the content of the two interviews it is also clear that the geographical position of the two museums and the type of tourism that characterises them, as reported at the beginning of paragraph 4, strongly influences the online and offline marketing and communication choices made by the two realities, which have been manipulated to create as much value as possible for the visitor and at the same time create greater awareness for the potential user. We find confirmation of this in the fact that Museo Mine, being closely linked to the community of Castelnuovo dei Sabbioni and to visitors who are usually already well informed on the subjects covered in the Museum, has managed to almost completely eliminate offline communication channels, managing to concentrate everything in effectively in digital ones. The Chianti Sculpture Park on the other hand, being in a place that tends to be more subject to international or national tourism, is also still linked to offline communication channels that allow it to reach certain types of users that would be lost only with the use of digital, this strategy it is implemented, as explained in the interview, through the use of brochures within accommodation facilities and similar (see Fig.1).

In both cases, however, a positive outcome emerges in terms of feedback, interaction and communication with users, resulting from the use of marketing strategies based on the use of new technologies and communication and promotion tools such as social networks

Finally, as regards the topic of sustainability, in both cases we find a good application of technology in the field of social sustainability aimed mainly at breaking down cognitive and linguistic barriers, especially thanks to the tool of applications and QR codes with audio guides. From an energy sustainability point of view, however, there is still a low use of new technologies for energy efficiency and the massive reduction of waste, due to a lack of funding in this area.

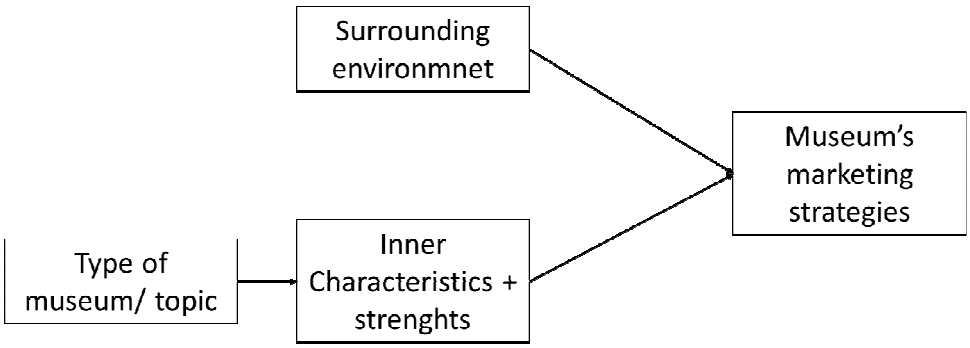

Fig. 1: Interpretative Framework 1. Source: own elaboration.

7 CONCLUSION

In conclusion, the qualitative cross-sectional analysis carried out between the two case studies gives us an image of the Italian cultural industry which confirms what was anticipated in the literature, i.e. an increase in

competitiveness, value created for the user and interaction with it found following the adoption of the new marketing 4.0 technologies also in the structuring phase, as well as implementation, of the marketing and communication strategies of each museum.

However, all of this is counterbalanced by the need to hire or train personnel who have specific skills in the field of digital transition, in order to exploit the maximum potential that the adoption of new technologies in the cultural field can offer.

Furthermore, other conclusions also emerge from this analysis; it is in fact clear that the intrinsic characteristics of each of the two case studies and their geographical position are two elements of great influence in the choice of the technologies used and the marketing and communication strategies chosen and more in general of the level of digitalisation of the two case studies. The strong bond with the Castelnuovo dei Sabbioni society and with the community of mining route enthusiasts who characterise the main target segments of the Mine Museum, as well as its geographical position which excludes it from mass tourism, have meant that it has built and strengthened a certain communication and marketing structure based on inclusion and dialogue with the user, choosing to do so via the website and social channels, mainly used, albeit with diversified content, like a museum logbook. On the other hand, however, we observe how the reality of the Chianti Sculpture Park, given its geographical position, decidedly subject to non-mass but still consistent international and national tourism, and considering the particularity of the contemporary art sculptures that characterise it, has decided to base its strategy on the use of social media mainly as a promotional tool aimed at creating as much awareness as possible about the existence of the sculpture park, and as an educational tool so as to increase the quality of the visit for the user, making it more aware and engaging, as well as managing to attract new potential visitors, this also thanks to the use of influencer marketing. These factors also implied the possibility of doing without, or not, offline distribution channels, which in the first case was possible, while in the second case, considering some reference targets, it was not.

It also emerges that the use of new technologies, in addition to bringing enormous benefits from the point of view of creating customer value and awareness, if channelled effectively and efficiently could also bring great benefits from the point of view of environmental sustainability, reducing waste and optimising consumption, thus increasing profits. However, to achieve this objective, the need arises to have specialised personnel as anticipated, as well as to obtain greater funding in this area.

Finally, another interesting aspect is also highlighted from this analysis: we observe how the concept of the use of technology for both cases analysed is mainly reflected in the desire to create an authentic value for users, creating awareness on important issues for the two museums, but also as a tool that makes the two realities known and appreciated.

From this research it is also possible to offer an interesting suggestion to museums and institutions with similar characteristics of the two analysed. It would be worthwhile to plan sustainable strategies in the museums. Particularly, considering the nature and the location of the analysed ones, environmental sustainable actions might not only be beneficial for the company and the surroundings, but they could also catch the attention of those customers with a particular attention to the environment.

This research is not without limitations. In particular, we analysed only its cases, with the risk of subjectivity in the analysis of the results (Gibbert et al. 2008). However, this also gives the possibility of suggesting future lines for research, therefore indicating the possibility of validating the first results obtained thanks to the development of research based on multiple case studies that also include companies from other countries.

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🏆 *reviewed paper*

SMEXI – a Data-Based Approach for the Small-Scale Investigation of Sustainability Goals in Cities

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1 ABSTRACT

To address the wide range of global challenges and a more sustainable society, the UN Sustainable Development Goals (SDGs) were developed. They are a set of 17 global, interconnected goals and provide a comprehensive framework for governments, organizations, and communities to work towards common objectives. When aiming at a data-bsed approach to promote a sustainable development, it is necessary to identify for each SDG associated indicators and data sets that provide insights into the status quo or past developments. Existing approaches that aim to provide such data-based information for cities are often limited regarding the spatial resolution of the cities under consideration: they only allow the exploration and analysis of SDGs on a macro level, usually the complete city. However, cities are not homogeneous – different quarters vary a lot with regard to their population, usage, building structure, etc. Even inside of quarters, social disparities can typically be determined. Thus, to accurately identify existing problems, and to improve living conditions accordingly, an analysis at macro level is not enough. The SMEXI (Small Scale Exploration of SDG Indicators) tool presented in this work tries to overcome this limit and enables users to track the progress of SDGs in cities at a fine-grained level.

Keywords: SDG, planning, smart city, sustainability, development

2 INTRODUCTION

Cities worldwide face various complex environmental, social, economic, and governance challenges, amplified by ongoing crises such as the Covid-19 pandemic or consequences of military conflicts. It is increasingly evident that the multifaceted nature of these problems requires comprehensive, holistic approaches instead of attempts to find solutions that only focus on individual problem aspects. Ideally, the challenges are tackled by always aiming at a more sustainable development, i.e., a development that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations 2015a).

The challenges for sustainability in cities have evolved over time, with the roots of modern concerns tracing back to works like the groundbreaking report titled “The Limits to Growth” of the Club of Rome (Meadows 1972) or the collection “Small Is Beautiful: A Study of Economics As If People Mattered” (Schumacher 1973). They highlighted the finite nature of Earth's resources and the potential consequences of unchecked population growth and industrialization. To address the wide range of global challenges and to promote a more sustainable and equitable world, the UN Sustainable Development Goals (SDGs) were developed as part of the 2030 Agenda for Sustainable Development that was officially adopted by all member states of the UN in September 2015 (United Nations 2015b). They are a set of 17 global, interconnected goals and address a range of social, economic, and environmental challenges. The role of the SDGs in promoting more sustainable cities lies in providing a comprehensive framework for governments, organizations, and communities to work towards common objectives.

When aiming to promote a sustainable development, it is critical for any type of stakeholder to first obtain a clear picture of the situation in the region of interest. Accordingly, it is necessary to identify associated indicators for each SDG that provide insights into the status quo or past developments. And last not least, these indicators can only be examined properly if data sets with information about them are available and accessible. Several approaches exist that aim to provide such data-based information for cities, e.g., the SDG tracker by Our World in Data (https://ourworldindata.org/sdgs) or the Open SDG platform (https://open-sdg.org/). Yet, these tools are often limited regarding the data sources used, but above all when it comes to the spatial resolution of the cities under consideration: they only allow the exploration and analysis of SDGs on a macro level, usually the complete city. However, cities are not homogeneous – different quarters vary a

lot with regard to their population, usage, building structure, etc. Even inside of quarters, social disparities can typically be determined. Thus, to accurately identify existing problems, and to improve living conditions accordingly, an analysis at macro level is not enough.

This paper first discusses the problem context and research background. After an overview of SDGs and related indicators and data sources, the methodologies employed and the design and development of the SMEXI prototype are presented. The tool itself is then explained in detail, followed by the results of a first evaluation. The paper concludes with a summary and an outlook to future work.

3 RESEARCH BACKGROUND

Several approaches exist that offer a data-based approach to track SDGs for specific regions. It is common for them to rely on a global set of indicators for all 17 SDGs. E.g., (Arbab 2022) suggests an indicator system for measuring city sustainability based on a systematic literature review. On the one hand, this facilitates global comparisons. On the other hand, data availability for all indicators might be inconsistent across countries, regions or cities, potentially leading to biased assessments. Also, such indicators usually do not capture local nuances, variations, and disparities within countries or regions. E.g., trackers may show that a country has made significant progress on SDG 1 - No Poverty - but they may not provide the data to show that there is a significant gap between urban and rural areas. Examples of such approaches are the German SDG-Portal[1], the Eurostat SDG country overview[2], and the dashboards by the European Sustainable Development Solutions Network (SDSN)[3].

The Open SDG Platform[4] is an open data and technology framework that claims to be designed to assist in driving global action toward a sustainable and equitable future. By facilitating the collection, management, and dissemination of SDG data, the platform aims at empowering stakeholders to track progress, assess impact, and make informed decisions to drive change. The open source platform is characterized by its distinctive features, collaborative framework, and nuanced approach to data visualization. It can be customized to align with specific contexts and priorities, and allows users to create dashboards customized to their needs. However, this approach could not be used as the basis of our work as their solution works by drilling down information specific for an SDG and its dimensions for a region. One of our goals is to enable users to understand how multiple SDGs and their dimensions are related and affect each other, for example the relation between Income Distribution (SDG 8) and the Amenity Distribution in a region, where one can notice regions with higher income have access to diverse and better infrastructure than those with lower income.

In (Editorials 2018), the authors provide a comprehensive overview of the state of SDG tracking and identify key challenges and opportunities. They state that progress on the SDGs is mixed, and that progress is often uneven across countries and regions. The authors identify several data gaps and methodological challenges that need to be addressed to improve the quality of SDG data. These challenges include:

- Reliable and timely data on many of the SDGs is often scarce or unavailable, particularly in developing countries.
- Even when data is available, it is often not comparable across countries or regions. This is due to differences in data collection methods, definitions, and reporting standards.
- The quality of SDG data can be poor, due to factors such as measurement error, bias, and incompleteness.
- To address these challenges, the authors propose a number of strategies, including:
- Investing in the capacity of national statistical agencies and developing innovative data collection methods could help in analyzing data more accurately.
- Investment in data infrastructure can provide access to data and technologies that can be used to improve data quality and improve current comparison and evaluation methodologies.

[1] see https://sdg-portal.de
[2] see https://ec.europa.eu/eurostat/cache/infographs/sdg-country-overview/
[3] see https://eu-dashboards.sdgindex.org
[4] see https://open-sdg.org

- Promotion of new data sources, such as the use of satellite imagery, mobile data, and other innovative data sources to fill data gaps. An example is the usage of satellite imagery to bridge gaps in land use data in a region, such as the forest coverage.
- Techniques and processes such as developing data visualization tools and training decision-makers on how to use the SDG data effectively, can help improve the use of data for decision-making.

The authors highlight the need for greater collaboration and coordination among national governments, international organizations, and civil society to improve SDG tracking. This includes developing a common understanding of the SDGs, establishing a shared set of indicators, and developing a global monitoring system. The paper concludes by calling attention to the importance of SDG tracking for achieving the SDGs. The authors argue that by measuring progress on the SDGs, we can identify what is working, what is not working, and what needs to be changed to achieve the goals.

4 THE SMEXI TOOL

In order to examine the potentials and challenges of an approach that allows spatially differentiated analyses of SDGs within cities, the project SMEXI (Small Scale Exploration of SDG Indicators) was initiated at DFKI. Using the city of Kaiserslautern, Germany, as a first test bed, the aim is to provide an interactive and adaptable, digital platform facilitating the tracking of SDGs in cities at a small scale. Realizing such a platform entails the tasks (1) to identify indicators and (potentially) available data sets for all SDGs, (2) to examine, preprocess and integrate these data sets, (3) to determine spatial granularities that correspond to meaningful examination areas, and that can be described properly with the identified data sets, (4) to find suitable forms of presentation for the (aggregated) data on SDGs, and (5) to develop a software architecture and identify suitable components and interfaces.

A first prototype of SMEXI was realized at the end of 2023 making use of various data sets from the city administration of Kaiserslautern and other, mainly publicly available sources. It is a web-based tool that uses local districts and statistical districts as spatial units for fine-grained examinations. It offers means to compare different parts of a city, and to manually define scores for different SDGs.

4.1 Identification of indicators and data sets

The successful implementation of the SMEXI prototype hinges on a thorough understanding of the data sources and their origins, elucidating how they contribute to monitoring and tracking SDGs. We first need to identify the data we need and its dimensions, which is a challenging task. We identified that the most efficient way to tackle the challenge is through the following steps and considerations:

(1) To decide the data we need, we start by understanding the underlying intentions of the SDGs, and for each SDG discuss in detail questions we want to answer with respect to the SDG. In this step, it is very important to involve experts for specific fields such as health or education. As an outcome, a set of indicators is identified for each SDG.

(2) For each identified indicator, we need to research if data sets exist that provide respective information. Such data can come from different sources as shown in Table 1. When selecting a data source, quality characteristics such as completeness, accuracy, actuality, and being devoid of bias must be considered (Priestley et al 2023). We aimed at only using freely available, open data to foster the transferability of our approach. We were able to procure our data sets from publicly available data sources as well as from our professional networks who work with and had access to the data sets we required to present our solution. We also considered the ethics of presenting our data in the visualizations and questioned ourselves on how diverse users can interpret them, keeping in mind that visualizations can be misused to portray and focus on negativity and shortcomings (Williams 2020). It is important to have discussions and debates with diverse groups and experts on the selected approach.

It is important to be careful to not raise our expectations that every SDG and indicator that we identified in step (1) can be perfectly covered. The thought and goal is to ultimately support users and not to provide a perfect answer.

4.2 Determination of spatial units used

Since we were aiming at facilitating the tracking of SDGs on a micro level, meaningful spatial units had to be identified that allow such a small-scale examination. In our test scenario we either had the possibility to rely on existing predefined structures used in German administrations, to define spatial units on our own, or to allow end users to specify regions of interest. This decision was strongly influenced by the spatial structures for which data exists or can be merged. It turned out that, among other things due to data protection aspects, a large part of the data within our test scenario does not exist or cannot be created for freely definable regions, but only aggregated to spatial sizes established in the administration, specifically "city districts" and the smaller scale "statistical districts". These are geographical subdivisions within a city or municipality used for the collection and analysis of statistical data. Relying on these granularities allowed us to make use of the majority of data sets.

Data Set	Description
Shape Data	Our main goal is to monitor sustainability objectives at a small-scale level, achieved by dividing the city into smaller regions. The smallest regions are identified in our prototype as statistical regions which serve as the basis for our sustainability analysis, employing a bottom-to-top approach where they are grouped into larger municipality regions for comprehensive data aggregation. The data set structure includes GeoJSON data points for statistical regions, each with a unique identifier crucial for associating social data sets, while the municipality/city districts data set utilizes a mapping file to group statistical regions effectively.
Crowdsourced/ User Generated Data	In our context, such data is mainly gathered by means of volunteered geographic information (VGI). This refers to geographic data voluntarily contributed by individuals or communities, often through platforms like OpenStreetMap (OSM) to collectively create and share spatial information. They cover various aspects such as public infrastructure, transportation, amenities, and land use, aiding our analysis of diverse SDGs.
Administration Data	Refers to data gathered, maintained, and managed by municipal authorities, encompassing various aspects such as demographics, infrastructure, services, and policies, which are utilized for urban planning, governance, and decision-making processes within a city.
3rd Party Data	This fefers to collections of data obtained from organizations outside a public administration, often provided by external vendors, government agencies, research institutions, or commercial data providers. A few examples of where we use 3rd party data are in the visualizations for income distributions and educational qualifications. It is important to note that both this, and Administration Data are meticulously selected based on the important information they contain about the identified SDGs and additional criteria such as richness, reliability, and accessibility.

Table 1: A brief overview of different types of data sources used in the SMEXI prototype.

4.3 Data processing and querying

We generally receive the data from the sources shown in Table 1 in a format that requires certain preprocessing steps in order to be usable within our system. We will briefly discuss how we process this input data and rationalize our chosen storage approach, Elasticsearch.[5]

The data is received in a variety of data formats such as GeoJSON or CSV. We start by exploring the existing dimensions of the data received in order to understand and how we can leverage them within our SMEXI prototype specifically for the multiple SDGs we are tracking. Consider a scenario where we have data with information on infrastructure, we can proceed by solving for how we extract and process the information to be used in tracking for amenities and transportation by categorizing the infrastructure type and extracting supporting data from the same data source or additional data sources. To be able to do more than get the information stored in it in the current state, we wanted to be able to make queries to the data set. Among others this is realized by leveraging the technical capabilities of Elasticsearch (Gormley & Tong 2015) which has rich features such as ranking query results from which we can select the most desired results from. E.g., when we query OSM data for information on green spaces in a region, we can easily query different representations such as 'green' or 'green_community'.

[5] see https://www.elastic.co

In a further data processing step, we need to make sure that data that does not have a POI characteristic is associated with the spatial units we use in SMEXY.

4.4 Functionalities

The objective of the SMEXI prototype is to enable diverse stakeholders to track and analyze SDGs, which is possible through map visualizations, a panel with visualizations for different SDGs, data sets as well as a "Region Index Value", and through a mode that allows to compare different regions.

4.4.1 Map visualizations

The map visualization plots shapes corresponding to the selected spatial granularity (i.e., "city districts" or "statistical districts"), upon which information relevant for the examined SDGs is presented. Administrators have the flexibility to define the size and shape of these regions, enabling detailed exploration on a small scale. The map visualizations are dynamically rendered using OpenStreetMap (OSM) tiles, which are based on web maps. These tiles are meticulously crafted from a wealth of open data, including contributions to OSM, GPS information, and visual input from volunteers. The OSM tiles are flexible and can be custom crafted by users according to their need, for our prototype we utilize the standard OSM tile layer and the transport tile layer which focuses on providing all transportation-related details in a map visual. Figure 1 presents the view of the prototype on initial load, when we click on a region on the map to the right, the SDG data associated with the region is presented in the left column of the prototype.

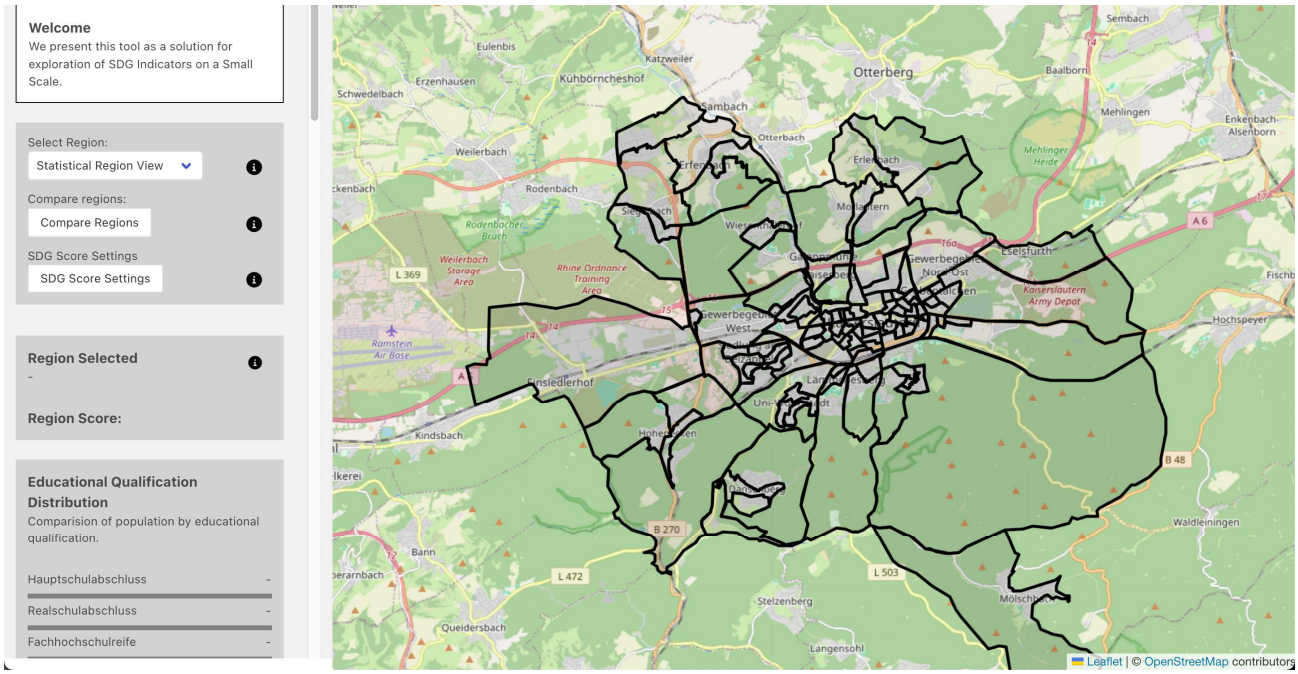

Fig. 1: Initial view of prototype on load. To the right we have a map visualization with plots of different regions. To the left we present the data visualizations specific to the region under consideration.

4.4.2 SDG/Data visualizations

On selection of a region on the map, the data associated with it is visualized to allow the user to quickly understand the information presented. As data visualization plays an increasingly crucial role in decision-making, storytelling, and communication, ethical considerations become paramount. The creation and presentation of the visualizations were discussed at length and in great detail throughout the implementation process to ensure that they are accurate, truthful, inclusive, and depict context clearly. The prototype visualizes data specific to the region which relates to various SDGs. Table 2 describes which SDG is tracked for analysis in a data visualization. As seen in Figure 1, these data visualizations are loaded in the left column of the prototype based on the region selected on the map.

4.4.3 Region Index Value

The determination of an index for tracking SDGs for each region involves a comprehensive approach, integrating insights from various research papers (Tuholske et al. 2021, Memmel et al 2021) and establishing

standardized formulas (Randall & Baetz 2015). In initiating the calculation process, each setting defines an ideal value (Kurth et al. 2023), serving as the starting point for subsequent score computations. These ideal values align with standards established by relevant research papers (Grisolia & Torchio 2022), reflecting an ideal benchmark. Acknowledging the diverse nature of regions, the solution introduces sliders that allow users and policymakers to adjust values within the predefined ideal range. This flexibility ensures that regions can be accurately characterized based on their unique conditions and attributes. The aim of this technique using a weighted value for a region and comparing it with others is to bring quality to all regions as a start before moving up to a better index score.

Data Visualization	**SDGs Tracked**
Income Distribution	SDG 8
Educational Qualification Distribution	SDG 4
Population Age Distribution	SDG 10 and SDG 11
Population Diversity	SDG 5 and SDG 10
Amenities Distribution	SDG 3 and SDG 11
Transport Distribution	SDG 8 and SDG 11
Car Fuel Type Distribution	SDG 7 and SDG 13

Table 2: Correlation between the visualizations in our prototype and the SDGs they address.

4.4.4 Comparing Regions

This functionality is designed to establish a comprehensive methodology for comparing two regions. Through the utilization of visualizations and the computation of index scores for each region, the objective is to spotlight variations between different regions.

This information serves as a valuable resource for policymakers, offering insights into regional characteristics. By identifying specific scores and dimensions that may benefit from introduction or improvement, this approach contributes to the pursuit of greater equality between regions.

4.5 Architecture and components

The technical architecture (Fielding et al. 2000) of the SMEXI prototype is provided in Figure 2. We now briefly discuss the rationale behind choosing the technology stack. For the client side, which represents the user interface and functionality that users interact with directly, we decided to use a no-framework solution and leverage the complete functionality of JavaScript. This was done since our goal is to offer an effective long term solution, so we wanted to avoid challenges when frameworks are deprecated and no longer supported which can cause potential code rewrite. D3.js and OSM are chosen as they are open-source and have a large community of developers releasing new features for data visualization. Our data sets are stored in Elasticsearch indices, which describes our database technology. Its features of aggregating query results, retrieval speeds, and query ranked results are leveraged, as discussed in Section 4.3.

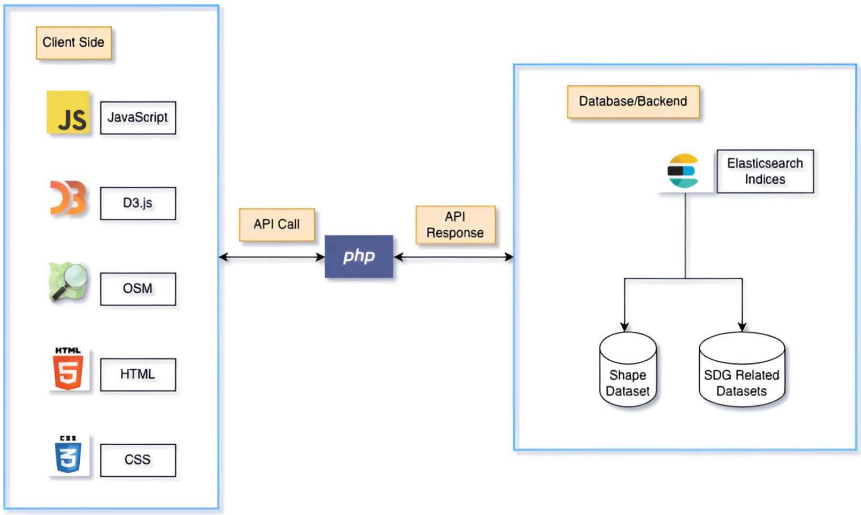

Fig. 2: Architecture diagram

We developed our code base using the Model-View-Controller (MVC) (Reenskaug 2003) chosen for its code modularity and reusability which are the most desirable principles in modern development.

We will now briefly present the controllers which are responsible for handling user inputs and managing the flow of data and control in the code in Table 3.

Controller	**Responsibilities**
App Controller	• Controls execution from first load to the end of life. • Manages data flow and events between the Map Controller and Region Information Controller.
Map Controller	• Query the data sets. • User click events on a region plot on the map visualization as seen to the right in Figure 1, transfers control to the Region Information Controller with the data bound to the region to be used for generating the region's visualizations.
Region Information Controller	• Instances of all the visualization models are maintained. • When data received from the Map Controller on user region selection, it transmits data to each visualization model. • Calculation of the Regional Index Score as discussed in Section 4.4.

Table 3: Overview of the responsibilities of the controllers.

Models represent the data and business logic and are responsible for storing data, performing computations, and enforcing business rules. Models encapsulate the application's state and behavior. A controller has the capability to instantiate multiple models needed as seen in Figure 3 where the Map Controller is linked to the Map Model in a one-to-one relationship, indicating a single instance of the map model. Conversely, the Region Information Controller has a one-to-many relationship with its associated models, allowing the controller to create multiple models as required.

Model	**Responsibilities**
Map Model	• Switching between map tiles, which are intended to provide users distinct perspectives and information layers in a map view. Our prototype has the base map and transport map tiles. • Oversees the creation, editing, and deletion of plots on the map visualization.
Donut Chart Model, Progress Bar Chart Model, & Pyramid Chart Model	• Generates and manages the state of the visualizations for the charts.

Table 4: Overview of the responsibilities of the models.

Services play a crucial role in encapsulating the logic associated with making requests to the database through API calls, handling the responses, and managing data. Services abstract the complexities of network communication and data manipulation, providing a clean interface for other parts of the solution to interact with external APIs or internal data sources.

Services	**Functionalities**
Elasticsearch Query Service	Encapsulates functions that support the generation of complex queries by the Elasticsearch standard and processing the response from the queries into a desirable data structure format used in the prototype.
Overpass Query Service	Interacts with the Overpass API, extracting OpenStreetMap (OSM) data. It forms queries based on Overpass API protocols, filtering options extend to various shapes via GeoJSON, enabling tailored data retrieval.
PubSub Service	Based on the Publish-Subscribe design pattern, coordinates communication between controllers or models. It handles event distribution and subscriber management, allowing communication without direct dependencies.

Table 5: Overview of the functionalities of the services.

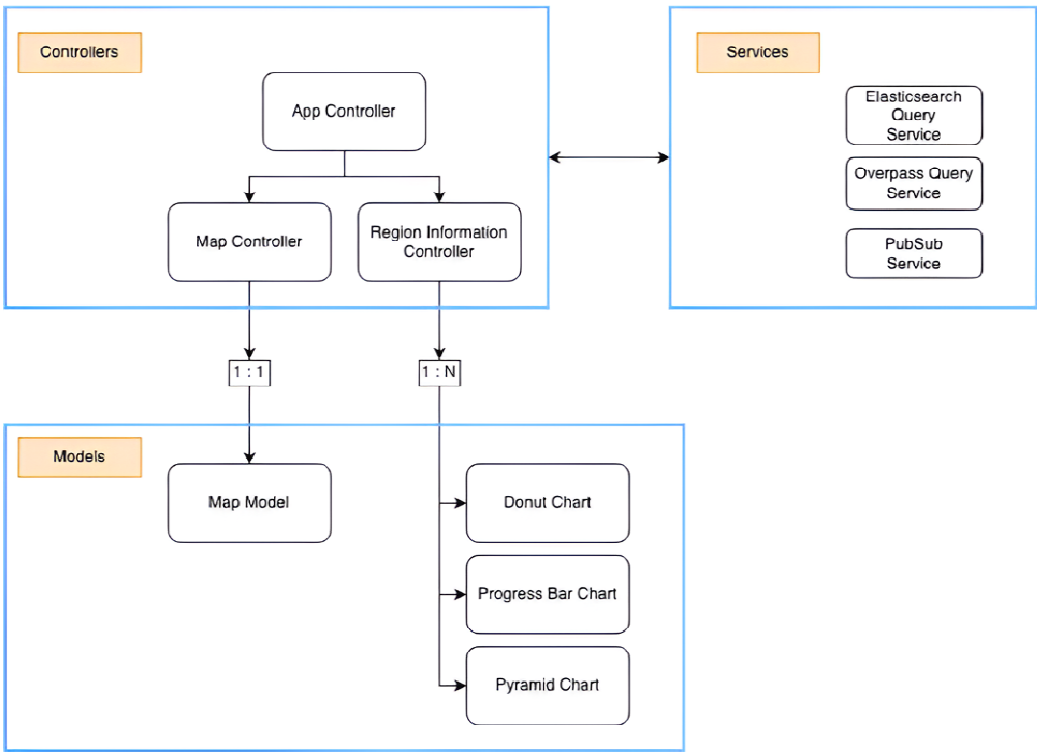

Fig. 3: MVC Design

5 PRELIMINARY EVALUATION RESULTS

As not all the data required for a complete evaluation of the SMEXI tool was available at the time of publication, the corresponding results are not yet available. However, we engaged with diverse stakeholders and sustainability experts during the development of the system. Their feedback helped us improve the solution's effectiveness, practicality, and accessibility for a broader audience. Specifically, we focused on making visualizations, regional scoring, and comparison methods quick and easy to understand within the SDG context. This aimed to prevent misinterpretations and support users in drawing meaningful conclusions from the data. Our work unfolded through iterative development stages. We continuously presented our findings to the city of Kaiserslautern, framing our solution as a potential input for ongoing initiatives. This ensured our work aligned with local context and broader development goals. Furthermore, we showcased our solution at consortium meetings of the project "Ageing Smart".[6] We demonstrated its ability to aggregate municipal data and provided interactive examples for data exploration. The positive feedback and insightful questions fueled further development, confirming the solution's effectiveness, practicality, and its potential to empower stakeholders for positive change.

6 SUMMARY AND OUTLOOK

The small-scale consideration of SDGs in cities is an important task to be able to make informed decisions for sustainable development, and to adequately consider the given diversity and heterogeneity in urban environments. The SMEXI prototype implements such an approach and uses the established geographical subdivisions of "city districts" and "statistical districts" for this purpose. This ensures that the largest possible number of available data sources can be used. In addition, these are spatial dimensions that were already considered useful for small-scale studies based on various considerations by city administrations. These spaces are therefore also particularly suitable for an investigation of SDGs.

The identification and integration of indicators and corresponding data sets for individual SDGs is a process of central importance and requires both in-depth knowledge of the goals and the availability and accessibility of data, particularly within urban administrations. In many cases, such data sets only provide information about a limited number of facets of an SDG, yet it can support decision makers and experts in an analysis

[6] see https://ageing-smart.de/

process and serve as a motivation to carry out further investigations, or to contribute with further information that can be integrated into the system.

In the future, we plan to publish the SMEXI software as open source and to realize further use cases in order to learn more about potentially relevant data sets, and about further configuration means that are required to adapt the tool to specific local settings.

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Spatial Justice in the Distribution of Smart City Digital Technologies: Three Area-Based Case Studies of Free Municipal Wi-Fi in the City of Tshwane, South Africa

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1 ABSTRACT

In South Africa, urban planning legislation entrenches the principles of equity, good governance, and spatial justice. In countries such as China and India spatial inequalities in the allocation of digital technologies are high. Cities need to distribute digital technologies fairly and equitably so that opportunities are availed to citizens in ways that promote spatial justice. In a country such as South Africa, this is vital because apartheid has entrenched planning practices of favoring certain places at the exclusion of others. This paper provides an attempt to understand the extent to which the allocation of free Wi-Fi sites in the City of Tshwane is done in ways that promote the implementation of the principles of spatial justice, access, and equity. The paper focuses on three areas only: Pretoria Central Business District (CBD), Mamelodi Township, and Soshanguve Township. The paper used a mixed method research approach, combining a desktop literature review, empirically gathered views of some key stakeholders, as well as Geographic Information Systems (GIS) map analysis of the free Wi-Fi sites in the three areas under analysis. The authors find that there is some degree of spatial justice in terms of allocating free Wi-Fi sites in the three areas. However, it is not clear if the City has a policy to inform the allocation of the free Wi-Fi infrastructure in communities. It is also not clear if the City has some scientific, objective tool/criterion for allocating free Wi-Fi sites in different regions/areas. In the absence of such a framework, key decisions about allocating free Wi-Fi infrastructure could be based on political considerations, and threaten the sustainability of the programme. Going forward, the City needs to develop an objective policy framework, which should encapsulate principles of spatial justice, transparency, fairness, and equity for allocating free Wi-Fi infrastructure.

Keywords: Spatial justice, fourth industrial revolution, smart city, free municipal Wi-Fi, City of Tshwane

2 INTRODUCTION

The objective of this paper is to do a spatial analysis of the free Wi-Fi sites in three specific areas within the City of Tshwane, and have some informed understanding of the extent to which the free Wi-Fi infrastructure is spatially spread to accommodate a majority of residents in line with the urban planning principle of spatial justice. The three areas covered in the case study are Mamelodi Township, Soshanguve Township, and the Pretoria CBD. The outcomes of the exercise show the extent to which spatial justice principles are implemented in both central city urban core areas and townships.

3 METHODOLOGY

The paper used a Geographic Information System (GIS) maps analysis to make observations regarding the extent to which the spatial allocation of the free Wi-Fi sites in the City of Tshwane promotes the urban planning principle of spatial justice. The maps were created using Quantum GIS (QGIS). QGIS is recommended and trusted for urban planning studies (Kamaraj & Rangarajan, 2022; Ha et al., 2012). The City of Tshwane shape file was created. The final maps contain a scale bar, north arrow, and legend. The study also included the perspectives of the key stakeholders in the South African local government environment, including the views of experts who were interviewed in this study. The interpretation of the findings of the GIS maps and those of stakeholders and experts provided some nuanced understanding of the extent to which the principle of spatial justice is applied in allocating free Wi-Fi infrastructure in the City of Tshwane.

4 LITERATURE REVIEW

South Africa's past apartheid spatial planning created spatial injustice. Indeed, spatial inequality is one of the strongest predictors of disparities in the digital inequality stack. Rural-urban digital inequalities affect both emerging and developed economies. For example, rural internet users in the USA experience low-speed internet infrastructure. In addition, they have low access to internet devices in comparison to urban users. The same has been found in the United Kingdom (UK). The situation in India is also bleak. Just over 20% of people in rural India have access to internet connectivity, which is 45% lower compared to urban areas. China faces similar challenges, with the internet penetration rate in rural being less than 38% (Robinson, et al., 2020).

The solutions to remedy such situations include the provision of good quality internet and digital training. Taiwan has managed to implement this strategy with success. The introduction of mobile technologies can also go a long way to halting the widening of the gap between rural and urban residents. Important is to remember that technology supply must be augmented with capacity-building initiatives, along with investment in infrastructure and improvement of information services (Robinson, et al., 2020).

In South Africa, the Spatial Planning and Land Use Management Act, Act 16 of 2013 (SPLUMA) remains one of the most important pieces of legislation for municipalities to drive spatial transformation. In this regard, some of the principles promoted by this Act are inclusivity, efficiency, equity, etc. Other principles are good administration, spatial justice, efficiency, sustainability, and resilience (RSA, SPLUMA, 2013). A key implication of this Act is that any municipality in South Africa that chooses to invest in smart digital platforms and/or technologies must ensure that such investments will have the effect and outcome of building and constructing inclusive cities, communities, and people (spatial justice). In other words, municipalities must not use digital technologies and innovations to entrench and reinforce apartheid spatial injustice in South Africa.

There are several dimensions of spatial inequality (Turok, Scheba, & Visagie, 2017). Scholars such as Todes (2006, 2008, 2011, 2012) have researched extensively on spatial planning in the South African context. The South African apartheid spatial planning regime produced the 'apartheid city model'. So, the new planning regime under the democratic dispensation still must ensure spatial justice. The reality is that South African spatial planning is grappling to meaningfully respond to the real needs of disadvantaged groups. There are still stark spatial inequalities in South Africa (Shifa, David, & Leibbrandt, 2021).

Mkhize (2018) investigated spatial inequalities in Msunduzi municipality and concluded that spatial inequalities can be addressed by ensuring that infrastructure is located in all spaces. This means that spatial inequalities can be reduced by ensuring that there is a link between the provision of infrastructure and spatial planning. Through implementing the concept of 'polycentric' development; infrastructure can be directed to places closer to where people stay/reside, thus 'creating a city within a city'. Turok, Scheba, & and Visagie (2017) argue that another way of reducing spatial inequalities is through better regulation.

Physical location is one of the key dimensions of spatial inequality (Turok, Scheba, & Visagie, 2017). In terms of policy approaches on how to respond to spatial inequalities, there are two broad schools of thought. These are place-based, and people-centered approaches. The issue of spatial rebalancing can be necessary. People-centered approaches can be crucial for social stability and national cohesion. Spatially-blind approaches may disregard the special economic advantages of some spaces over others. A key weakness of the space-blind approach is that it overlooks the impacts (social, economic, etc.) of unevenly spread infrastructure. Place-based approach requires direct interventions, especially at the regional and/or local levels. Nonetheless, place-based approaches are not in themselves a magic wand (Todes and Turok, 2017).

Measuring spatial transformation can be done through the usage of a wide range of indicators. According to the South African Local Government Association (SALGA) Spatial Transformation Barometer (2022), in the key performance area of proximity and access, some of the indicators include daily commuting, commuting costs, access to public transport, access to roads, health, education, police station, etc. In the area of basic services and human settlements, the key indicators would include access to water services, energy/electricity, sanitation, waste/refuse removal, access to the internet, density, population change, etc. Other indicators include poverty, inequality, household composition, gender imbalances, dependency ratio, employment, education, skills, etc. Taiwan is one of the countries that has managed to use the provision of data to reduce

digital inequalities spatially. So, the introduction of digital technologies by cities can go a long way to enhance spatial justice.

5 PRESENTATION OF FINDINGS

The discussion covering the three areas follows below.

5.1 Mamelodi Township Analysis

The first area of focus is Mamelodi Township. Mamelodi is one of the oldest townships in Tshwane. This township was established in June 1953, then called Vlakfontein, according to the Group Areas Act. The aerial picture of Mamelodi Township is provided below (Figure 1):

Figure 1: Aerial picture of the Mamelodi Township, CoT. Source: CoT (2023)

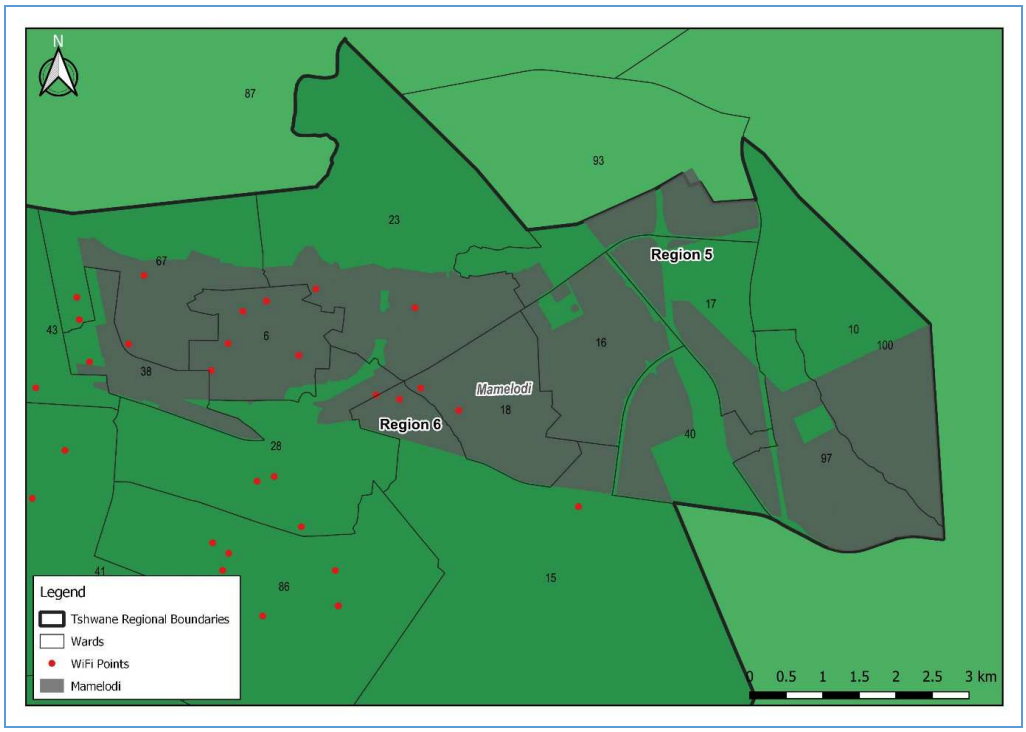

Figure 2: Spatial spread of municipal free Wi-Fi sites in Mamelodi Township, CoT. Source: Adapted from CoT (2023)

Mamelodi (affectionately called Mams) is still a black-dominated township, in terms of racial classification. Mamelodi remains one of the largest black townships in Tshwane, and certainly one of the top ten biggest townships in South Africa It is said that the name Mamelodi was given by the then South African State President, Paul Kruger because he thought Africans were able to whistle like birds (melody). The population of Mamelodi is approximately 334 557 and comprises no less than 110 703 households. Nearly all Mamelodi residents are African (98.8%), and 61% reside in formal dwellings (CoT, 2023).

5.2 Mamelodi Township Municipal free Wi-Fi Spots spatial analysis

Figure 2 shows the spatial spread of free Wi-Fi sites in Mamelodi.

Mamelodi Township is part of Region 6 in the City of Tshwane. Approximately 8 wards can be seen on the Mamelodi map above. In terms of spatial analysis, nearly all wards seem to be provided with free Wi-Fi sites. However, Ward 16 may need some attention.

5.3 Soshanguve Township Analysis

Soshanguve is situated about 30 kilometers north of Pretoria. The aerial picture of Soshanguve Township is provided next (Figure 3):

Figure 3: Aerial picture of Soshanguve Township, CoT. Source: CoT (2023)

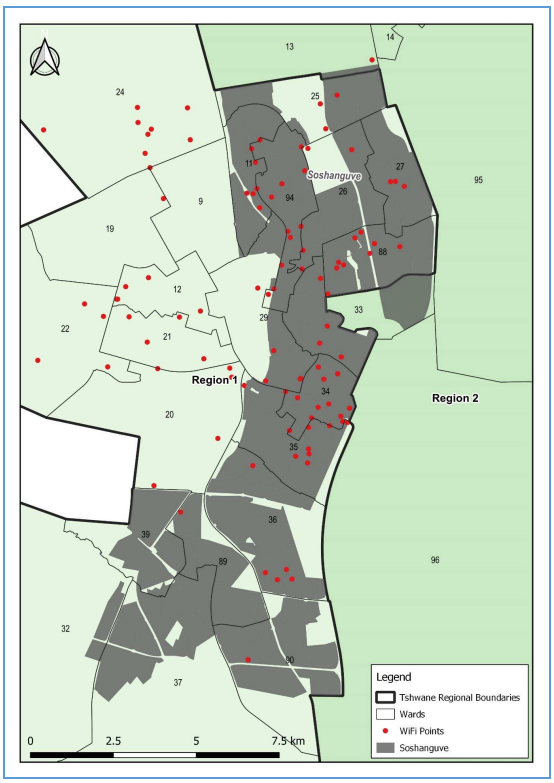

Figure 4: Spatial distribution of municipal free Wi-Fi sites in Soshanguve Township, CoT. Source: CoT (2023)

Soshanguve (affectionately called Sosh) is still a black-dominated township, in terms of racial classification. Established circa 1974, Soshanguve remains the largest black township in Tshwane and one of the top ten biggest townships in South Africa. The name Soshanguve is an acronym for Sotho, Shangaan, Nguni, and Venda. This makes Soshanguve a multi-ethnic community. The population of Soshanguve is more than 800,000. It is estimated that the population of Soshanguve would reach 1 million by 2025. Currently, nearly all Soshanguve township residents are African (99.2%) (CoT, 2023).

5.4 Soshanguve Township Municipal free Wi-Fi Spots spatial analysis

Figure 4 shows the spatial spread of free Wi-Fi sites in Soshanguve.

In terms of spatial analysis, nearly all areas (wards) in Soshanguve seem to be provided with free Wi-Fi sites. Some wards even have more than 1 free Wi-Fi site. This is encouraging, as it enhances the accessibility of the sites.

5.5 Pretoria CBD Analysis

The Pretoria CBD analysis follows next. The aerial picture of Pretoria CBD and surrounding areas is provided below (Figure 5). The CBD and the surrounding areas form part of the administrative capital of Tshwane. Strategic places in this area include the Union Buildings, the State Theatre, and the Reserve Bank of South Africa. Another important consideration is that there are many schools and institutions of higher learning in the area, including the Tshwane University of Technology, the University of Pretoria, the University of South Africa, and several private colleges. Embassy houses are hosted here as well (CoT, 2023).

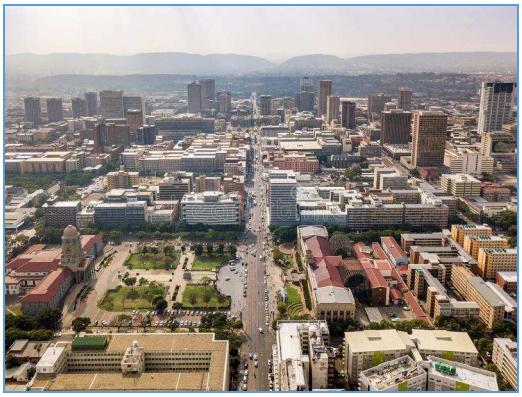

Figure 5: Aerial picture of Pretoria CBD and surrounding areas, CoT. Source: CoT (2023)

Some of the historic buildings include the Pretoria City Hall, Church Square, Sammy Marks, the Transvaal Museum, Pretoria Zoo, and the Tshwane Tourism Office. There is also Burgers Park, which is now a national monument, in addition to being the oldest park in the city (CoT, 2023). All these strategic spaces attract the need for free data, especially by the student population, and other users for commercial, business, recreational, and social media purposes.

Figure 6 shows the spatial spread of free Wi-Fi sites in the Pretoria CBD areas.

Although the Pretoria CBD is very small in terms of space, it is a high-density area. The allocation of sites also seems more equitable as well, similar to allocations in Mamelodi and Soshanguve townships. However, it would seem that the CoT is strategically prioritizing this area for free Wi-Fi infrastructure deployment as this area is one of the strategic areas for promoting the brand of the city to global visitors and other players. Access to data in the CBD is key for a range of functions.

6 STAKEHOLDER AND EXPERT INTERVIEW ANALYSIS

There are mixed messages regarding whether the Tshwane Free Wi-Fi is serving all people of Tshwane equally well irrespective of their geographic location. Some respondents believe that the municipal free Wi-Fi is only beneficial to those living within the range of the Wi-Fi. Other participants (46.7%) believe that free Wi-Fi is making an immense contribution in terms of enhancing spatial justice, followed by 25% who feel that it is making a modest contribution. A majority of stakeholders (72%) either strongly agree or agree that

since the introduction of the Tshwane Free Wi-Fi, some people no longer have to travel to the central city/town to do things that can be done through digital platforms.

Figure 6: Spatial distribution of municipal free Wi-Fi sites in the Pretoria CBD, CoT. Source: CoT (2023)

7 DISCUSSION OF FINDINGS

The authors managed to do a spatial analysis of the free Wi-Fi sites in three specific areas Mamelodi Township, Soshanguve Township, and the Pretoria CBD. Through the use of Geographic Information System (GIS) maps analysis and engagements with stakeholders and expert interviews, the authors conclude that the spatial allocation of the free Wi-Fi sites in the City of Tshwane promotes the urban planning principle of spatial justice. The conclusion is important, considering South Africa's past apartheid spatial planning, which birthed spatial injustices, among others. One of the lessons from Taiwan is that the provision of good quality internet and digital training is important. Important is always important to remember that technology supply must be augmented with capacity-building initiatives, along with investment in infrastructure and improvement of information services (Robinson, et al., 2020).

The City of Tshwane seems to be on course in ensuring that a key implication of the SPLUMA, i.e. that any municipality in South Africa that chooses to invest in smart digital platforms and/or technologies must ensure that such investments have the effect and outcome of building and constructing inclusive cities, communities, and people (spatial justice) is being advanced. As scholars such as Mkhize (2018) found, spatial inequalities can indeed be addressed by ensuring that infrastructure is located in all spaces. This paper conforms to this notion. So, spatial inequalities can further be reduced in Tshwane by ensuring that the links between the provision of infrastructure and spatial planning are strengthened practically. Through implementing the concept of 'polycentric' development; free Wi-Fi infrastructure can be directed to places closer to where people stay/reside.

Indeed, physical location is one of the key dimensions of spatial inequality (Turok, Scheba, & Visagie, 2017). The question of whether to respond to spatial inequalities, through a place-based or people-centered approach is important so that the issue of spatial rebalancing can be necessary. Spatial justice is not an end in itself. Proximity and access to other facilities and services, such as public transport, access roads, health, education, police stations, etc. are important as well.

Although the authors find that the City of Tshwane seems to be on the right track in terms of ensuring some degree of spatial justice in the allocation of free Wi-Fi sites in the three areas under the study, there are some concerns. The main concern is that it is not clear if the city has a policy with some scientific, objective tool/criterion to inform the allocation of the free Wi-Fi infrastructure in different regions and/or areas. This is so, even though the city has some basic data that can assist in making decisions that are informed by facts. For instance, in terms of population, Soshanguve has about 334,577 people, whilst Mamelodi and Pretoria CBD have 403,162 and 741,651 respectively. In terms of population density, Soshanguve has about 3180 persons/km2, whilst Mamelodi and Pretoria CBD have 7403 persons/km2 and 1079 persons/km2 respectively. The dependency ratio in Soshanguve is 44.2, 35.7, and 33.4 in Mamelodi and Pretoria CBD respectively. Regarding average household size, the situation in Soshanguve is 3.7, 2.9, and 2.6 in Mamelodi and Pretoria CBD respectively. All this data is available on the website of the StatsSA, and the city can use this type of data to inform its decision-making processes.

8 CONCLUSIONS

Spatial injustice can threaten urban sustainability. However, in this paper, the authors conclude that similar to Taiwan, the City of Tshwane seems to be on the right track in terms of using the provision of data to reduce digital inequalities spatially. However, it is not clear if the city has an objective tool to inform decision-making regarding the allocation of digital technologies in different regions/areas. In the absence of such, key decisions about allocating free Wi-Fi infrastructure could be based on political considerations, thus threatening the sustainability of the programme. Going forward, the City needs to develop a robust policy framework policy to guide the implementation of the principle of spatial justice in allocating digital technologies.

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Spatial Strategies for Economic Growth within "Net Zero Land Take"

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1 ABSTRACT

In 2013 the European Parliament adopted a target of no net land take by 2050 in the EU as part of the seventh Environment Action Program. In Belgium, the highly fragmented urban region of Flanders has expressed the ambition of no net land take by 2040. Slowly, regional planning instruments are put into place to achieve this goal. Most of the planning tools however still have a functionalist, growth oriented conceptual basis, e.g. the demand forecasts for economic zones that are used to promote green field development. We need to develop regional planning tools that lead towards land take reduction.

In previous work, we developped a method for forecasting economic space demand in urban and peri-urban areas, within the context of net zero land take. The quantitative result provides insight in the part of economic space demand that could be accommodated in mixed use areas (economy and housing), and the demand that can only be met in functionally segregated economic zones. In this paper we will focus on a case where a local planning authority tries to combine spatial and economic policy strategies to promote economic growth without resorting to new greenfield development.

The research starts with a short critical review of existing functionalist planning practices and their close link to real estate development. In a second part we have a close look on four potential spatial-economic strategies that might cater to our objective. The first strategy stays close to the existing planning practice, but goes more into detail and resorts to a form of micro-zoning. A second strategy focusses on the development of financial instruments and covenants. Transferable development rights are explored in the third strategy, where innovative land value capture can steer owners into developing space for economic activities. The last strategy is a strong local public development company, that buys land and building to (re)develop in line with the needs of the local economy and the ambitions of the spatial policy plan.

An ex-ante evaluation of these strategies shows the potential of each approach, and highlights the organisational and financial consequences of each strategy. Local authorities can make an informed decision on what strategy and planning practice is fit for purpose in their specific situation. We will use the case of Lier (a small city between Antwerp and Brussels) to illustrate the positive and negative effects of each strategy, as the city has a strong ambition to remain an attractive location for industrial investment.

Keywords: space demand, zoning, net zero land take, economic development, new planning practises

2 NO NET LAND TAKE AND FUNCTIONALIST PLANNING

2.1 EU policy

In 2011, the European Commission presented the 'Roadmap to a Resource Efficient Europe', which set out a number of targets for sustainable resource use. One of the main objectives was to achieve "net zero land take" by 2050. Following this, the European Parliament (2013) adopted a target of no net land take by 2050 in the EU as part of the seventh Environment Action Program. In Belgium, the highly fragmented urban region of Flanders has expressed the ambition of no net land take by 2040. Slowly, regional planning instruments are put into place to achieve this goal. Most of the planning tools however still have a functionalist, growth oriented conceptual basis, e.g., the demand forecasts for economic zones that are used to promote green field development. We need to develop regional planning tools that lead towards land take reduction.

Net zero land take means no more increase in the net area used for urban development, infrastructure and other human activities. This means that new developments must be compensated by reusing existing buildings and infrastructure, or by returning land to nature. In other words, the policy of net zero land take aims to reduce land take in Europe by preventing further urbanisation and infrastructural developments at the expense of natural ecosystems. Land take is the amount of land used by human activities, e.g. for urban development, recreation, infrastructure and industry.

Meeting the target of net zero land take means that land take will no longer increase, which in turn can help preserve and improve soil quality, biodiversity, reduce pressure on natural resources and reduce negative impacts on the environment.

Reducing land take can be achieved in various ways, for example by reusing existing buildings and infrastructure, improving land use planning and planning, promoting high-quality resource use and circular economy, and encouraging sustainable mobility. Thereby, reducing land take is an important part of a sustainable policy, as it contributes to preserving the natural environment and the long-term livability of our cities and communities.

2.2 Implementation in Flanders

The Flemish ‘bouwshift’ (Construction Shift) is a policy initiative that falls within the broader policy of net zero land take. It aims to improve spatial planning in Flanders by strengthening urban cores and reducing the fragmentation of open space. Specifically, the Flemish bouwshift involves paying more attention to the densification of towns and villages, reusing empty buildings and developing vacant land. This is accompanied by a reduction in the development of new buildings in open space, thereby reducing land take.

To achieve these objectives, several policy measures are proposed. For instance, more investment should be made in renovating existing buildings, new developments should be concentrated in urban cores, and businesses and infrastructure should be better clustered to counteract fragmentation of open space.

The end result will therefore be that when space is taken, it will have to be compensated elsewhere. In other words, functions will have to shrink - in terms of land take - to make room for something else.

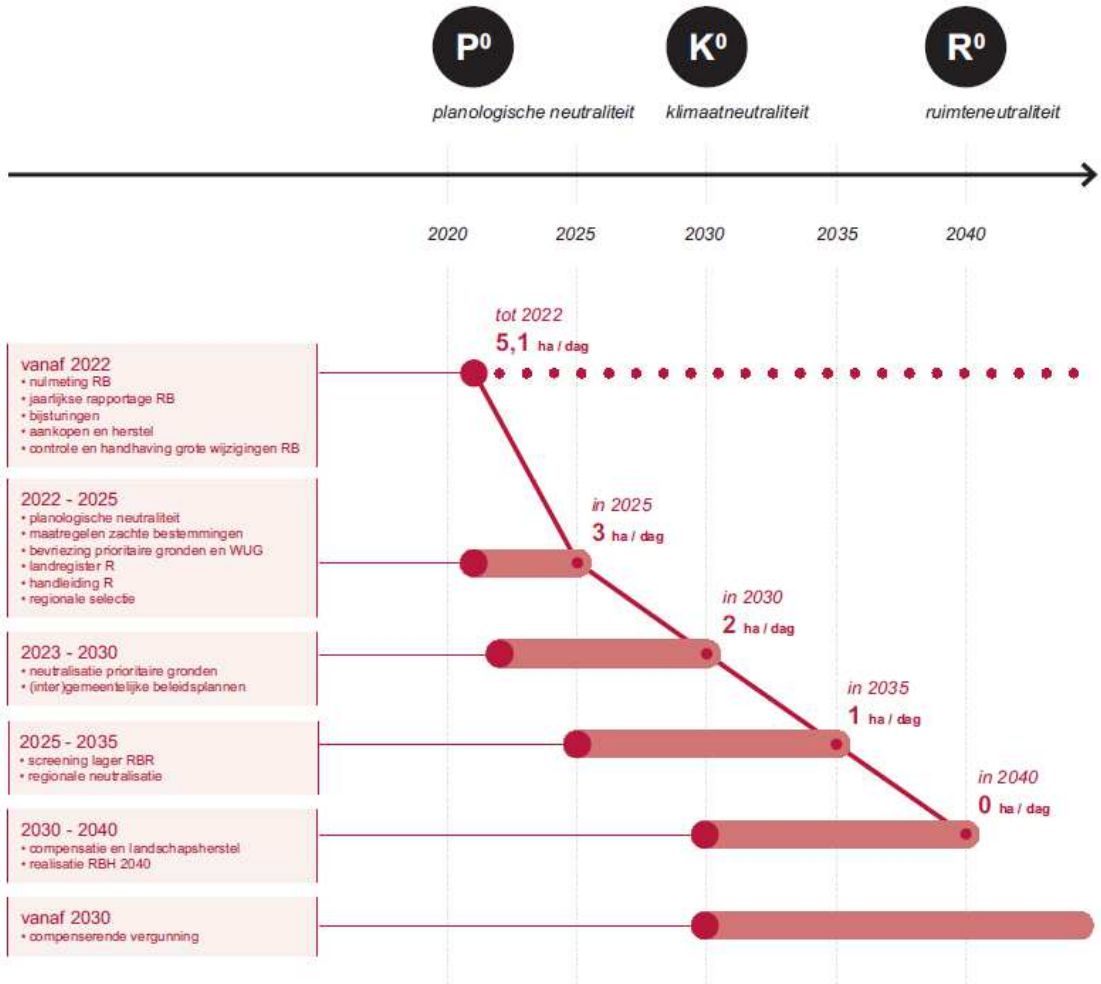

Figure 1: schematic timeline to reach net zero landtake in Flanders (Taskforce bouwshift, 2022)

Figure 1 shows the recommendations of the ‘taskforce bouwshift’, who were commissioned to draft a roadmap to the implementation of net zero land take in Flanders. In the scheme they propose a three step

approach: first to introduce the 'planological neutrality', which means that the amount of buildable land in the (comprehensive) land use destination plan can no longer grow. If a municipality, province or the regional level proposes to change agricultural land use (in the plan) to housing, recreation or industry, they have to compensate. The second phase focusses on 'climate neutrality', where the land use destination of unbuild, but buildable land that has to play a crucial role in adaptation to climate change is changed into open space. In this stage there is no compensation in the land use plan, but land owners can claim financial compensation. The third and final stage is to be reached in 2040 and looks at the actual settlement area as the maximum land take. This implies that new developments on open space can only be allowed if this is compensated by eliminating (demolishing) existing land take elsewhere in Flanders.

Currently, only the first step is put into legislation. The more complex second and third phase are not easy to implement in the Belgian context, and innovative planning instruments need to be developed. Traditional land use planning in Belgium has two main ways of financing these goals: the first is through subsidies for the realisation of natural areas, public infrastructure, recreational and cultural spaces; the second is by creating additional land value that private owners and developers can reap by building housing, commercial buildings, offices,…

2.3 Economic growth and the concept of no net land take

Economy needs space, and the transition toward circular economy requires growth. Recent EU initiatives to push forward the return of essential economic activities (batteries, personal protective equipment, textile recycling,…) and the transition to circular economy will all increase the demand for industrial accommodation, especially for production and logistics. To reconcile urban and economic growth with the no net land take policy, there are currently two main territorial strategies. The first is to intensify the current zoning plan, meaning that more houses are accommodated in existing residential areas and more economic floor space is provided in economic zones. The second is to allow more mixed use in cases where it is acceptable from a environmental and social point of view. The orange strategy path in figure 2 shows that, while both territorial strategies are needed, there will always be societal needs (roads, big new investments, inperfection in spatial planning instruments) that cannot find a place. The most probable political outcome is that these socalled exceptional needs require additional space. The no net land take goal will not be reached. An open space reclamation strategy and instrument (light green path) needs to be developed that can actually deliver a no net land take future. Only when we combine this with the intensification and mixed-use strategy we arrive at a future where affordable economic space can be provided in the long run.

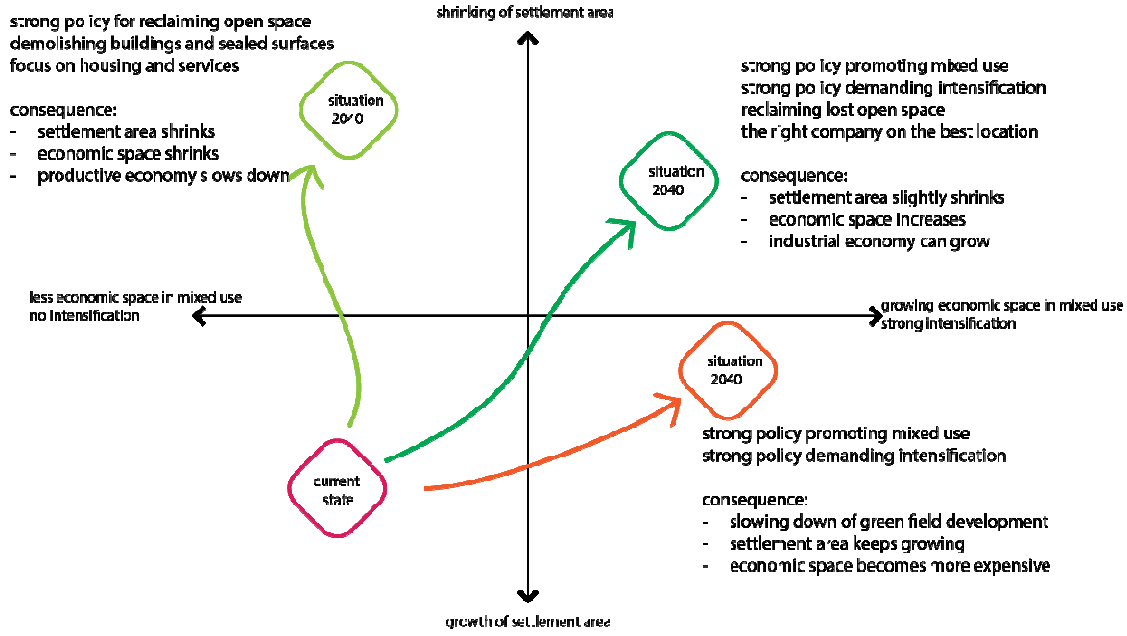

Figure 2: potential policy development paths for no net land take and the consequences for economic activities

3 LIER CASE STUDY – PLANNING PRACTISE

3.1 Economic situation in Lier

While developing the Economic policy framework for Lier, a small city (37.000 inhabitants) southeast of Antwerp, it became clear that a new spatial-economic approach is needed if the city wants to retain its economic position in Belgium. Lier has a strong service economy, combined with a good number of medium sized and large industrial companies. The current 5-year economic forecast predicts an employment growth of almost 8%. If Lier wants to accommodate its share of this growth, it will need to provide the necessary space, especially for the growth in the industrial and logistics sectors.

Currently, there is only a few industrial spaces that are available on the market. An online survey shows that there is an urgent need for both large buildings (over 15.000 m²) and many smaller units. We assume that this type of demand will continue over the next years. On the private market, there is a tendency to buy large industrial buildings, and split them into smaller units. The result is that the city loses the large accomodation, and the smaller companies find inadequate space, as they benefit from a more mixed, urban environment. Before the 'Bouwshift', the city would start the planning process to change agricultural land into a new industrial business park. The No Net Land Take policy makes this impossible, so another approach is needed to keep providing affordable and adapted economic accomodation in Lier.

3.2 Four implementation models

From the current planning practice in Flanders and recent research and debate we selected four potential methods for providing affordable economic accomodation in the long run, within the context of No Net Land Take (or bouwshift). In this paragraph we will explain how the four models (micro-zoning, financial incentives, transferrable development rights and public land policy) can be implemented. The next paragraph will focus on a theoretical evaluation of these models.

3.2.1 Micro-zoning

The first model, micro-zoning, takes the current planning practice of (rather generic) land use plans with planning prescriptions to another level. The idea is to use the same instrument to make really specific and detailed planning prescriptions to differentiate between (1) areas for large economic units, high ceilings, lots of space for heavy goods vehicles, (2) areas where smaller units are allowed in multiple storey buildings and (3) residential areas with an obligation to provide super-mix live-work environments. From a planners point of view all this is feasible and can be put in a plan. Usually there is no clear view on the actual demand and potential market uptake for the spaces prescribed. This is why the planning prescription remain rather general, and detailed prescriptions are often left out of the final plan. The key question for micro-zoning is how to make sure that there is a market for the units allowed in the planning prescriptions.

The main difficulty to use micro-zoning as a method to provide economic units in a no net land take context, is that it is not easy to change the rules and adapt the prescriptions to fast changing economic reality. A change of the land use plan normally takes at least 3 years to be adopted, and requires a huge financial and labour effort from the local government.

3.2.2 Financial and fiscal incentives

In the second model we combine property taxes, land value capture, VAT on construction and subsidies in one instrument. As a flat rate will either overshoot or miss the point, this model with only work if the public authorities use these financial incentives in project based discussion with a developer. The final agreement is put in a (publicly available) covenant. This requires the public administration to have the necessary skills to go into an open, constructive debate with developers on the aditional costs to provide large industrial spaces, or to put part of the units on the market at an affordable price. Currently there is only experience with the different instruments separately, and different government levels are competent for the diverse fiscal and financial instruments. To apply this on a local level, competences need to be transferred to the local level for the implementation of the no net land take policy.

3.2.3 Transferable development rights

Around Lake Tahoe in California and Nevada the authorities developed a lot of experience with transferable development rights. In recent literature we find examples all over north America, and recently also in India

and other fast-growing countries. The model only works if (1) there is a good and stable zoning or land use plan, (2) there is a transparant and widely accepted method for defining the development rights of each parcel, and (3) an independent trading mechanism to allow people to sell their development rights to someone else who can transfer it to another parcel. The trading mechanism can also provide multiplicators, so if you take away development rights from a parcel that is badly located and you transfer them to a better location you can multiply the building rights. When this is the case, the development rights of badly located parcels are worth more money, and thus more likely to be tranferred.

When looking at the requirements of the third phase in figure 1, it seems that there are not many alternatives to this as an instrument that can actually deliver the shifting of land take from one place to another. Probably this model will be developed as a planning instrument in different regions in Europe, or it might even take a similar form to the carbon emission trade system on a European level. For the moment there is no or limited experience with this model, and the instrument needs to be developed for use in the European context.

3.2.4 Public investment in industrial land

The last model is to install a public development company that can by land and building and (re)develop the necessary economic accommodation. Belgium has a long standing tradition in public development companies on a local and intermunicipal level. In the 1970s these companies were used to build motorways and industrial business parks, from the early 2000s many flemish cities started their own development company to complement the market oriented developments. Mostly these urban development companies took up more difficult areas (eg with soil pollution) or implemented other goals such as affordable housing or super-mix developments. In this case we would use the public development companies to buy industrial real estate that can help achieving the goals of intensification, affordability and the growth of industrial economic space. The advantage of this model could be that it can accumulate financial means to slowly move from standard, easy to build and market spaces, to more complex, multi-storey, multi-user buildings. The latter currently only have a potential long-term yield in very tight market as the Brussels Capital Region, where industrial space demand is growing, while the offer is shrinking.

3.3 Ex-ante assessment and feasibility within the Belgian context

In this paragraph we test the four models to their ability to deliver the desired result, without producing inadvertent negative side effects. For Lier, the requirements and risks are:

- availability of a large industrial space (> 10.000m²)
- availability of many (5 – 10) small and medium sized spaces (100m²-600m²)
- space on the market at an affordable price (regarding the revenu in specific sectors)
- timely renovation of industrial buildings
- quality of available spaces correspond to the evolution of the economy in Lier
- avoid companies being priced out of Lier and forced to move to find an affordable location
- avoid shrinking of industrial space (eg replacement with higher value real estate: housing, offices,…)
- providing economic space comes at a acceptable cost (labour + investment) for the local government
- the policy can adapt to the fast changing economic reality
- is the local government able to implement the policy alone
- does the model help reach net zero land take target

All topics are evaluated for each model in table 1 by giving a qualitative assessment, followed by a general goodness of fit apreciation.

4 CONCLUSION

No net land take will prove to be a huge challenge to provide affordable industrial spaces, to accommodate for the needed and forecasted economic growth. Of the four models that were studied, only the public development company can deliver to the ambitions of the city of Lier. Luckily, they have an existing, strong public development company that has experience with developping industrial units. The public development

company is currently studying how to turn this into a long-term business case, and whether they need other public or private partners to deliver space for the future industrial economy.

	Micro-zoning	**Financial incentives**	**Transferable development rights**	**Public land policy**
Provide large units	Planning for different unit sizes will only deliver if the market can develop them with a profit. Large units will come at a higher price.	If financial and fiscal incentives can be easily adapted to development costs, large units will be provided.	If the development certificates and trading system works correctly, yes.	Yes.
Provide (many) small units	Planning for different unit sizes will only deliver if the market can develop them with a profit. Small units are easy to sell.	Small units will probably be developed in any case, regardless of financial incentives.	Small units will probably be developed in any case, regardless of transferable development rights.	Yes.
Affordability	Probably only a selling market, aiming at the highest yield.	Financial incentives can be used to cap prices, and to provide a larger variety of types of spaces.	More difficult to achieve as it is down to developers to define the price.	Yes.
Renovation is stimulated	No.	If this is included in the legal framework or covenant, yes.	Yes, it promotes redevelopment and intensification.	Yes.
Offer is related to the demand	Yes, through the market mechanism, so the lower end will have to rely on the secondary market.	If the incentives are related to the unserved demand, it will.	Yes, if the trading system is flexible and easy to adjust.	Yes.
Companies priced out	Yes, especially companies that need large spaces or cannot afford to pay a high price.	Not if the incentives work properly.	Probably, due to imperfections in the development rights trading system.	No, unless the construction cost is too high
Growth of industrial space	No, where allowed other functions will grow, industry will decline	Yes.	Yes.	Yes.
Investment cost for city	High. Making and updating spatial plans comes at an important cost	Low.	Low.	High, but with a good long-term yield
Labour cost for city	High. Making and updating spatial plans is very time consuming	High, because of the need to negotiate covenants and monitor the incentive rates.	Low.	High, but done by a public company or a public-private partnership.
Swift adaptation of policy	No. Adaptation of a plan will take at least 3 years (current planning system)	Yes.	Yes.	Yes.
Multi-level governance	City can act alone.	A legal framework is necessary, probably involving the federal and regional government	A new instrument needs to be developed by the regional and federal government.	City can act alone
NNLT is achieved	Yes.	Yes.	Yes	Yes.
Overall assessment	High investment, time consuming method, which will not meet the requirement of affordability. Industrial space will probably shrink.	Finetuning the financial levers and drafting covenants is time consuming. The legal framework needs to be put in place.	TDR on a regional level can be highly effective to steer investments. The lower end of the market will not be served. No experience in Flanders.	High investment, with a financial yield and a direct link between policy and action. Method can deliver on almost all points.

Table 1: Assessment of four implementation models for providing space for economic growth in the context of net zero land take.

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🏆 *reviewed paper*

Suitability of the Residential Location of Older People: towards a Typology in Flanders, Belgium

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1 ABSTRACT

Ageing-in-place is often a desire among older individuals and a basic principle of the Flemish care policy, which emphasizes informal care. However, it can also be seen as a normative framework, especially when alternative residential options are lacking or hardly accepted. Our prior findings indicate that older parents in Flanders (Belgium) generally reside in close proximity to their children. Most informal care is provided within the family framework, mainly by partners or children. This does not mean that they are always available, willing to help, or asked for help. Therefore a suitable neighborhood with enough amenities is another crucial factor to facilitate living independently at older age. However, there is insufficient understanding about both the current living environment and residential mobility of older adults. While existing (inter)national literature suggests low residential mobility among older adults, detailed insights into specific moving patterns, such as the balancing act between housing, proximity to children and neighborhood characteristics, are lacking. A GIS analysis is conducted based on data 1) on facilities, such as supermarkets, bakeries and medical facilities, 2) and the residential location of older people retrieved from the national population register. The aim is to evaluate whether each older individual's current residential location would support ageing-in-place, based on the assumption that this partly correlates with the availability of amenities and services. As a second step our research focused on the residential mobility between 2002 and 2017 and investigated whether those who changed their residential location did that towards a location that is (not) better equipped than the previous one. Our research shows that approximately one-fifth of older adults in Flanders (aged 65+ in 2002) changed their residential location between 2002 and 2017, excluding those who moved to nursing homes. While, in general, those who moved have improved their situation, complexities are revealed in terms of the living environment of those who did not move, asking for more research into the trade-off between housing, proximity to children and neighborhood amenities and services.

Keywords: older adults, neighbourhood amenities, moving, quantitative methods, Flanders

2 INTRODUCTION

In most European countries there is an emphasis on ageing-in-place, often combined with a re-emphasis on informal caregiving, which in reality is often provided by children. Therefore, in a previous REAL CORP contribution (Gruijthuijsen et al., 2022), we focused on the geographical proximity between older adults and their children in Flanders (Belgium). While these results show that, in general, the distance between older adults and children is quite limited, merely proximity to children is not enough to age-in-place. While we found that half of the older adults aged 80 or above, in 2017, lived within 2 kilometers from the closest child, others lived substantially further away. Furthermore, we noticed an increase in distance over time, which may lead to challenges in informal family care provision. Although international research shows that there is a strong correlation between providing informal care and geographical distances between parents and children (e.g. Hank et al., 2007; Knijn & Liefbroer, 2006), proximity alone cannot be a guarantee that informal care is provided, let alone on a frequent basis. Equally – or even more - important factors to age in place are related to the neighborhood and physical environment, such as the availability of (enough) services and amenities. While a supportive living environment is acknowledged when it comes to age-in-place, the focus is often too narrow and excludes the neighborhood. Even in discussions about the person-environment fit, the focus is mainly on housing, neglecting the physical environment (Sun et al., 2018). While research into ageing tends to stress macro-economic factors, such as pensions and healthcare expenses, or micro-level elements such as the dwelling, the neighborhood is little researched. Hence Greenfield et al. (2019) point to the need for a 'community gerontology' to take into account the level of the neighborhood and the living environment. While the Age-friendly cities network of the World Health Organization lists 8 interconnected

domains, and focuses on accessibility and age-friendliness of outdoor spaces and buildings, it does not say anything about the availability of amenities and services (beyond access to health care).

For this purpose, we have developed a classification of residential locations of older people in Flanders, focusing on the availability of amenities and services in the immediate surroundings. Not only the actual living conditions of older adults in terms of proximity to important amenities and services are at stake, but also the process of moving to locations that are less or better equipped. In section 3, we will briefly discuss the importance of the neighborhood at older age. Section 4 will introduce the methodology on the neighborhood classification and the moving patterns, followed by the results (section 5) and conclusion and discussion (section 6).

3 LITERATURE REVIEW: THE IMPORTANCE OF THE NEIGHBORHOOD AT OLDER AGE AND RESIDENTIAL MOBILITY

Ageing-in-place is often interpreted rather narrowly as a policy approach to help older adults remaining in their own family dwelling for as long as possible. However, the concept implies much more complexities and can better be considered as remain living in the own familiar environment (beyond the dwelling), with a certain degree of independence, instead of living in a residential care setting (Wiles et al., 2012). From this perspective, even moving to an adjusted apartment, or assisted living apartment in the same neighborhood can be considered as ageing-in-place. In that sense we can point to Martens (2018, p. 9) who states that "the meaning of "place" [in ageing-in-place] is no longer "home" but rather "neighborhood" and ageing-in-place can be seen as not having to move outside the neighborhood to receive care services. Of course this requires a neighborhood that supports someone's independency by offering enough amenities and services, social support, and a diversity of residential options. It makes sense that the focus with ageing-in-place is on the dwelling and whether it is (or can be) adjusted to current and changing needs, but not without taking into account whether the neighborhood is supportive for older people to keep a certain level of independence. Furthermore, the neighborhood is often considered a 'constant' or 'stable' factor, while neighborhood dynamics can affect ageing-in-place and the wish to stay or move (Lewis & Buffel, 2020). In general, the neighborhood can be an important push or pull factor when it comes to a residential move and it is shown that the quality of the neighborhood differs along the life course (Rabe & Taylor, 2010). De Jong (2022) shows that while factors related to the dwelling were the strongest predictors of actual mobility, the neighborhood explains a large share of the propensity to move. At the same time, it is known that older adults, in general, stay put and show a relatively low residential mobility (e.g. De Jong, 2022; Gillepsie & Fokkema, 2023). Residential relocations by older adults are often triggered by specific life events, such as a deterioration of the health status or widowhood (Bloem et al., 2008). The classic framework by Litwak & Longino (1987) which states that older adults in the United States make 3 moves: after retirement (often moves along longer distances), after experiencing moderate health problems (moving closer to children) and after having major forms of chronic disability (moves on short distance) is not easily applicable to the Western-European context, and especially to Belgium, in which residential stability has long been stimulated by the housing policy (focusing on home ownership and commuting instead of residential relocations and prioritising a stay in the family home until old age), and is still highly embedded in the current residential practices and patterns (Meeus & De Decker, 2015).

The neighborhood is getting even more important at older age. It is well-known that older adults tend to spend more time at home and in the neighborhood (e.g. due to mobility constraints) and are often more attached to the immediate surroundings (e.g. Varjakoski et al., 2015). Therefore, it is not surprising that Golant (2015) stresses the importance of the neighborhood to reach residential normalcy. Not being able to walk to familiar places anymore due to an unsupportive environment or the lack of certain facilities in the immediate surroundings impact the possibilities to age-in-place. Research shows that the quality of neighborhood services and amenities influences the well-being of older adults (Cramm et al., 2013). Nearby facilities and amenities are not only more important for older people who are more bound to the neighborhood, a walkable neighborhood also has important health benefits (e.g. Herbolsheimer et al., 2020). It is known that the built environment and presence of amenities and services influences walking behaviors among older adults (e.g. Yun, 2019; Levasseur et al., 2015), but also the sense of community (Zhang et al., 2017), which can all contribute to ageing (well) in place.

Shopping and health services are among the most frequently mentioned aspects that must be available in the neighborhood and are important reasons to move (König et al., 2019). It is therefore surprising that there is still limited insight whether older adults live at locations that are close (enough) to basic amenities and services. This is also true for Belgium. While studies have been done into the housing conditions (e.g. through a regular Flemish survey), the neighborhood is often left under researched. It can work also the other way around: do well-equipped neighborhoods offer suitable housing for older people? Research from the Netherlands Environmental Assessment Agency (PBL) in 2019 shows that suitable living environments (with basic amenities and services within 500 meter) often have a large share of homes that are not-suitable at older age, and thus points to a discrepancy between the neighborhood and the dwelling for older people. Furthermore, the same agency (PBL, 2023) also points to the need to get more insight into the spatial distribution of amenities related to health issues and whether these amenities and services fullfill the needs of the (local) inhabitants. All these aspects are equally relevant to Belgium, and therefore we aim at contributing to solve some of those knowledge gaps by looking into the proximity to amenities or services in the case of older adults in Flanders. The framework below (figure 1) shows several aspects (non-exhaustive) that might influence the suitability of the residential location to age-in-place. While we are aware of multiple factors that are at stake, in this paper we mainly focus on neighborhood amenities and the relation between residential relocations and the neighborhood (amenities). In a previous REAL CORP contribution (Gruijthuijsen et al., 2022) we focused on the distance between older adults and their children (in combination with some personal characteristics). In addition to a quantitative analysis, and as part of our research project, we did 68 interviews across Flanders to get more insight into the lived experience of ageing-in-place and the different trade-offs between the different push and pull factors that influence the decision whether to stay or move. These will be explored and connected to the data in future work and are beyond the scope of this contribution.

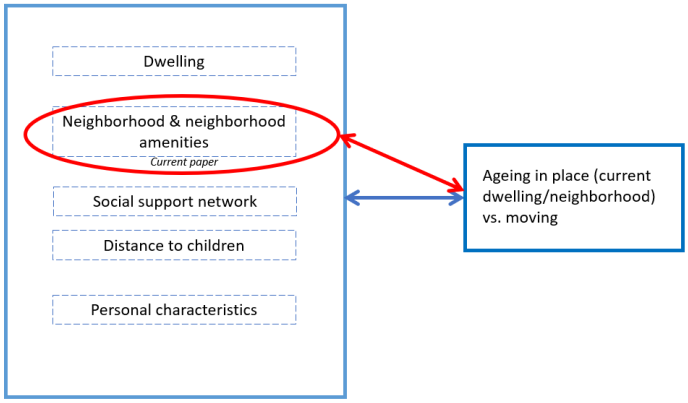

Figure 1: Suitability of the residential location of older people. Created by authors

4 METHODOLOGY

There are existing classifications in Belgium that focus on the level of amenities and services on the municipal level (De Maesschalck & Van Hecke, 2018), or combinations of amenities and services on a 1-hectare level (Verachtert et al., 2016 – VITO), but they are not specifically focused on older adults, and give no indications of the current locations where older adults live. Therefore, we had i) to indicate the location for each older adult for 2002 and 2017, based on the national population register and ii) to calculate the distance between the dwelling of each older adult and a selection of relevant amenities and services in both 2002 and 2017. This gives us not only insight in the actual living conditions of older adults in terms of proximity to important amenities and services, but allows us also to see whether older adults improved their situation in case they moved between 2002 and 2017. It has to be taken into account that we have data on services and amenities in 2016/2017 only. Therefore, an improvement or deterioration is not related to a change within the supply of amenities and services, but always a result of a residential relocation. Of course, amenities and services are not static, but these data is not available before this period. Therefore, we keep this level constant and use the data for 2017 also for 2002. As a consequence, and as example, it is likely that for some locations we underestimate the level of amenities in 2002, since some might have been closed down and not replaced by others (e.g. certain rural parts of the country).

To overcome computational limitations, and because of data constraints we focus on older adults who lived in Flanders in 2002 (see figure 2). Belgium (11,6 million inhabitants) is a federal state comprising three regions (Flanders, Walloon and Brussels Capital Region) and three communities based on language. For Flanders (the Northern Dutch-speaking region of Belgium) the region and community coincide. The regions and communities have far reaching autonomy when it comes to territorial and personal matters. That means the focus on Flanders (6,8 million inhabitants) is also justified by governmental responsibilities since care and spatial planning are largely regional competences. Furthermore, residential relocations between regions are very much limited (+- 22.000 people in 2022) (Statistics Belgium, 2023).

Figure 2: Flanders as study area. Source: Based on administrative borders (FOD Economy) and OpenStreetMap

4.1 Population data

Population data have been obtained from the Directorate-General for Statistics (Statistics Belgium), which is part of the Federal Public Service (FPS) Economy. For this specific paper we look into population characteristics in both 2002 and 2017. Our starting point is older adults (65+ in 2002) living in Flanders in 2002 who are still alive in 2017. Furthermore, for this contribution we only focus on older adults with children since, in a later stage, we will elaborate also on the level of amenities and services in function of the proximity to the adult children and the complex trade off between the neighborhood, housing and proximity to children. Therefore, our data cannot be considered a 'sample' since we consider the full 65+ population with children in 2002, although we left out the 65+ without adult children in 2002. We analysed slightly more than 300 thousand older adults, with approximately 615 thousand adult children. Our anonymized population records are incorporated in different datasets that can be linked via an identification number. The following datasets are relevant for this contribution:

- General population data: personal characteristics retrieved from the population register, the civil status, gender, age, country of birth, place of birth, nationality, first nationality and year of arrival in Belgium.
- Household and descendancy variables: anonymized identification number of the parents, household identification number, reference person of the household, household type, household position, household size, and relation between household members.
- Localization: coded address, duration of stay at the address, statistical sector (smallest administrative level), municipality.

Relevant for this contribution, the household variables give information about whether someone lives in a collective household, which we consider as living in a residential care setting because the Belgian Federal Planning Bureau and Statistic Belgium (2021) consider collective households as a very strong proxy for living in a residential care facility for those older than 65. For more information about how we calculated the distance between parents and children, we would like to refer to our previous REAL CORP contribution (see Gruijthuijsen et al., 2022). It has to be mentioned that most of these data are not freely available for the general public; the datasets have been created and made available by FPS Economy for the strict purpose of our research because they consider this research highly relevant as a basis for future policy making.

4.2 Other data sources

To assess the level of local services and amenities, we made use of the data by Verachtert et al. (2016), as part of a study commissioned by the Flemish Department of Environment and Spatial Planning as to delimit zones with a differentiated development potential based on transport nodes and proximity to facilities. In particular, we used several GIS point layers (or subsets of these layers) containing the locations of the following amenities: general medical practices, pharmacies, bakeries, butchers, small groceries stores (<400m2), larger groceries stores (>400m2), green grocers, post offices and bank and insurance offices. These data (except general practitioners – retrieved from the National Institute for Health and Disability – see further: Verachtert et al., 2016) are filtered from the VKBO (businesses data base) which are publicly available. In addition to the foregoing, we made use of the spatial dataset managed by the Flemish Agency for Care and Health (Flemish Government, 2023) to obtain the locations of local neighborhood centers, day care centers, residential care homes and assisted living unities. To calculate distances towards amenities and services we used the road network of Flanders and Brussels (Flemish Government, 2023b). Regarding the differentiation along spatial types and grades of urbanisation, we made use of the classification by Vanderstraeten & Van Hecke (2019). They distinguish city centers, agglomerations (densely built-up areas surrounding the city centers consisting of mixed functions), banlieues (sprawl area that is oriented towards the urban and agglomerations zones, mainly residential), a low(er) density commuting zone, and rural or non-urban areas.

4.3 Connecting the data and calculate distances towards facilities

For each amenity and service, we have created services areas along the road network of 0- 250 meter, 250 – 500 meter, and 500 – 1000 meter with ArcGIS. These are chosen in the framework of the goal of this paper, to see whether the place of residence allows to live independently in case someone cannot travel by car (anymore) and is dependent on the immediate surroundings. The categories were defined based on an extensive literature study on acceptable walking distances at older age and walking speed at older age (e.g. Yang & Diez-Roux, 2012; Saelens & handy, 2007, McCormack et al., 2008). We are aware that the physical geography (e.g. elevation) and quality of public space such as sidewalks and benches to rest can play an important part in the actual possible walking distance and speed, but we could not take these factors into account. The resulting ArcGIS shapefiles containing, for each amenity or service, the service areas, were converted into a raster dataset (for computational reasons) with cell size of 10m x 10m, with each cell indicating the distance category towards an amenity or service (0 – 250 m, 250 – 500 m, etc.). These cell values were extracted at the location (spatial join) of each older adult (coded address) to indicate for each individual the distance to a certain amenity or service. For further and other (statistical) calculations we made use of SPSS.

5 RESULTS

As mentioned we focus on those older adults with children that were alive in both 2002 (65+) and 2017 (80+) (hereafter just referred to as ‘older adults’). Older adults that passed away between 2002 and 2017 are not included, but can be subject of further research/analysis. Furthermore, changes between 2002 and 2017 are always a consequence of a residential move, since all our data regarding amenities are from 2017 and these data did not exist in 2002. First of all we will look into a rather static view of the suitability of the neighborhood in case an older adult relies on local resources that can be found at walking distance. Afterwards, we will adopt a more dynamic perspective by looking into residential mobility and the effect on the proximity to amenities and children.

5.1 Suitability of the current residential location

Figure 3 and Figure 4 show the proximity of older adults (65+ in 2002 – 80+ in 2017) towards the different selected neighborhood amenities and services. In 2017 we found that around 57% of all older adults live within 500 meters from a small grocery store. However, around one fifth of all older adults in 2017 have to travel more than 1 kilometer towards a small grocery store. A similar pattern can be detected when it comes to a bakery. When we look into first line medical facilities, we find that around 50% of all older adults live within 500 meters from a general practitioner, and around 40% live within 500 meters from a pharmacist. Interestingly, 4 out of 5 older adults live further than 1 kilometer from a local neighborhood center. Within the Flemish care policies, one of the main tasks for these centers is to support older adults to remain living at home independently and integrating formal and informal care. For some older adults proximity towards these centers can be very important, especially for those who cannot rely on informal (family) care givers. By comparing 2017 and 2002 we find that the distance towards the selected amenities and services decreased or, in other words, that the proximity increased: more older adults live within 500 meters of the selected amenities and services. That gives us a first indication that residential relocations are directed towards better equipped neighborhoods.

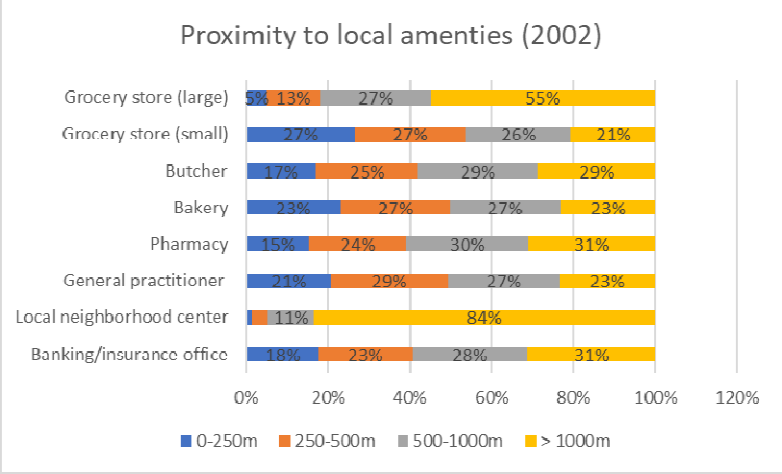

Figure 3: Proximity to local amenities and resources in 2002 (based on data in 2017). Source: data obtained from Statbel, VITO (based on VKBO), Agentschap Zorg en Gezondheid (2017)

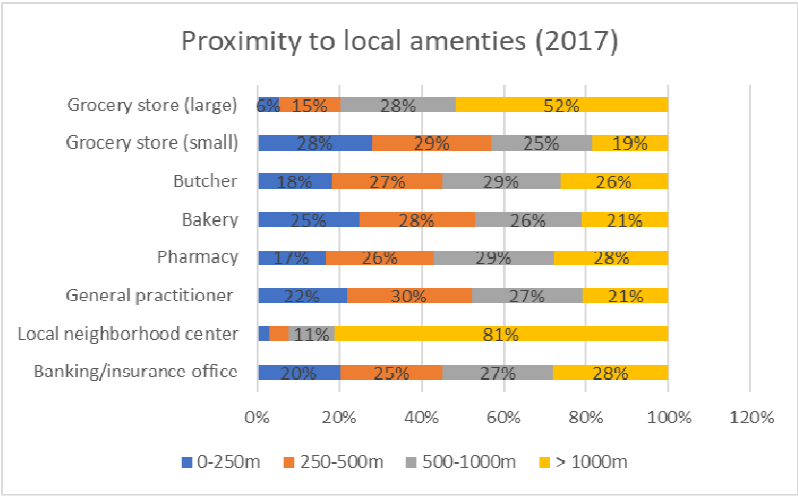

Figure 4: Proximity to local amenities and resources, 2017. Source: data obtained from Statbel, VITO (based on VKBO), Agentschap Zorg en Gezondheid (2017)

Further, the figures 3 and 4 do not take into account proximity towards a combination of those amenities and services. The assumption that it may be likely that someone who lives close to a supermarket or bakery also lives in close proximity to a general practitioner, is questionable. Living in close proximity towards food facilities but further away from medical amenities and services does not make the environment necessarily supporting at older age. Therefore, we grouped several amenities and services together and distinguished the following groups:

- Essential medical services (general practitioner, pharmacy, local neighborhood centers)
- Essential food amenities (small and large grocery stores, bakeries and butchers)
- Supporting services and amenities (Residential care facilities, Public Center for Social Welfare (OCMW), day care centers, health insurance offices and post offices)

Based on these groups, we have made different combinations to be able to decide whether older adults live at a location that is suitable to age in place if they would be dependent on the immediate neighborhood for amenities and services (see table 1).

Type of location	Description
Not suitable	No essential food or medical amenity within 1000 meters
Absolute minimum location	At least 1 essential food and 1 essential medical amenity/service within 1000 meter s
Moderately comfortable location	At least 1 essential food and 1 essential medical amenity/service within 500 meters
Suitable location	At least 2 essential food and 2 essential medical amenities/services within 500 meters
Amenity-rich location	At least 1 essential food and 1 essential medical amenity/service within 250 meters, and at least 1 essential food and 1 essential medical service within 250-500 meters.

Table 1: Type of location for older adults.

Type of location	2002	2017
Not suitable	22,1% (67243)	19,6% (59702)
Absolute minimum	28,0% (85476)	26,2% (79931)
Moderately comfortable	20,3% (61742)	20,9% (63703)
Suitable location	12,6% (38321)	14,1% (43013)
Amenity-rich	17,1% (52111)	19,2% (58544)
Total	100% (304893)	100% (304893)

Table 2: Percentage of older adults that lives in a certain type of location

Around 80% of all older adults in 2017 live at a location that has at least 1 essential food and 1 essential medical amenity or serivce within 1000 meters. That also means that almost 20% of all older adults live at a location that is not suitable to age-in-place in case someone depends on the immediate neighborhood on a daily basis (see table 2.), not taking into account many other factors such as social support networks and being able to drive a car. Around one third of the older adults lives at a location that is considered as suitable or amenity-rich. In reverse, this means that about two thirds live in less than suitable neighborhood conditions. Table 2 also shows that the share of older adults that live at a non-suitable location decreased between 2002 and 2017, which gives us another indication that residential mobility is at least partly aligned with moving to a better location.

Type of location	Average distance -2002 (median) (n)	Closest child – 2002 (median) (n)	Average distance – 2017 (median) (n)	Closest child – 2017 (median) (n)
Not suitable	11,6 km (4,9 km) (65963)	6,0 km (1,0 km) (65963)	12,8 km (5,5km) (57280)	6,6 km (1,3 km) (57280)
Absolute minimum	11,0 km (4,7km) (84682)	5,5 km (1,0 km) (84682)	12,2 km (5,5 km) (78096)	6,1 km (1,3 km) (78096)
Moderately comfortable	11,3 km (4,7 km) (61135)	5,7 km (1,0 km) (61135)	12,7 km (5,7 km)(62052)	6,4 km (1,4 km)(62052)
Suitable location	12,0 km (4,9 km) (37868)	6,3 km (1,1 km) (37868)	13,4 km (6,0km) (41712)	6,8 km (1,6 km) (41712)
Amenity-rich	13,7 km (5,2 km) (51381)	7,7 km (1,2 km) (51381)	15,1 km (6,3 km) (56785)	8,2 km (1,6 km) (56785)
Total	11,7 km (4,9 km) (301029)	6,0 km (1,0 km) (301029)	13,1 km (5,7 km) (295925)	6,7 km (1,4 km) (295925)

Table 3: Type of location and distance towards children.

Table 3 shows that the average distance to adult children as well as the distance to the closest child do not show a large variety depending on the type of location. In general, older adults in Flanders tend to live close to their adult children, although a small increase can be seen between 2002 and 2017. At one end of the scale, one can see that older adults living at a location that is not suitable tend to live further away from their children compared to those older adults living at an ‘absolute minimum’ or ‘moderatley comfortable’ location; and this does not change between 2002 and 2017. This might mean that older adults living at a less-equipped location in terms of amenities and services do not compensate this with a higher proximity to adult children. At the other end, older adults who live in an amenity-rich environment live considerably further from their children (average and closest) than older adults in the other locational types. A neighborhood with a high level of amenities and services might indeed offset for children living further away but the link is not clear and hypotheses are far-fetched. Some people with clear views on the importance of the proximity of amenities and services in general, might have made deliberate choices about where to live without taking the location of children into account or even assuming very early in their life cycle that children will settle far away from the family home.

When we look into more detail and differentiate the type of locations by the urban typology (and vice versa), we see that the majority of people who live at an amenity-rich location live in city centers (tables 4 & 5). The

results for the 'banlieues' or suburbs are quite interesting. Of all older adults living in an amenity-rich location, only 6,5% lives in a banlieue. Furthermore, it is striking that 60 percent of those living in a banlieue live at a location that is considered 'not suitable' or the 'absolute minimum'. This is even higher compared to those who live in non-urban (rural) areas which points to the problem of allotments that came into existence at the urban fringes in the seventies, eighties and nineties oriented towards car use, since they were very close to being amenity deserts while being characterised by an aging population at present.

Nevertheless it is a positive sign to see that the share of older adults living in amenity-rich location increased between 2002 (17,1%) and 2017 (19,2%) (not shown in table). For example, we noticed an increase for those who live in non-urban areas (11,4% in 2002 vs. 14,3% in 2017) and banlieues (8,4% in 2002 vs. 11,1% in 2017). This indicates that older adults in rural areas moved to better equipped locations, such as rural town centers which have more amenities and services. For all urban types, we have found that the share of people that lived at a non-suitable or absolute minimum location decreased between 2002 and 2017. While we might think of non-urban areas when it comes to less-equipped locations, we should stress that even in city centers, around 20% of the older adults live at locations that are not suitable or fulfill the minimum criteria only. Many nineteen and early twenty century belts are not well-equipped since in the twentieth century, small businesses had disappeared. This has consequences, also since we found that older adults in city centers, in general, live further away from their children.

2017	Not suitable	Absolute minimum	Moderately comfortable	Suitable neighborhood	Amenity-rich	Total
City center	5,7% (4091)	16,7% (11961)	21,3% (15238)	21,3% (15245)	35,1% (25114)	100% (71649)
Agglomeration	14,6% (7175)	31,1% (15271)	25,3% (12418)	14,7% (7243)	14,3% (7042)	100% (49149)
Banlieue	31,6% (10909)	27,9% (96120	19,1% (6575)	10,3% (3556)	11,1 (3822)	100% (34474)
Commuting zone	21,6% (13623)	30,1% (18997)	20,4% (12876)	11,8% (7486)	16,1% (10199)	100% (63181)
Non-urban	27,7% (23904)	27,9% (24090)	19,2% (16596)	11,0% (9483)	14,3% (12367)	100% (86440)
Total	19,6% (59702)	26,2% (79931)	20,9% (63703)	14,1% (43013)	19,2% (58544)	100% (304893)

Table 4: Urban typology by type of loation, 2017.

2017	City center	Agglomeration	Banlieue	Commuting zone	Non-urban	Total
Not suitable	6,9% (4091)	12,0% (7175)	18,3% (10909)	22,8% (13623)	40,0% (23904)	100% (59702)
Absolute minimum	15,0% (11961)	19,1% (15271)	12,0% (9612)	23,8% (18997)	30,1% (24090)	100% (79931)
Moderately comfortable	23,9% (15238)	19,5% (12418)	10,3% (6575)	20,2% (12876)	26,1% (16596)	100% (63703)
Suitable neighborhood	35,4% (15245)	16,8% (7243)	8,3% (3556)	17,4% (7486)	22,0% (9483)	100% (43013)
Amenity-rich	42,9% (25114)	12,0% (7042)	6,5% (3822)	17,4% (10199)	21,1% (12367)	100% (58544)
Total	23,5% (71649)	16,1% (49149)	11,3% (34474)	20,7% (63181)	28,4% (86440)	100% (304893)

Table 5: Type of locationby urban typology, 2017

5.2 Residential mobility and the neighborhood

Around 70% of all older adults in 2017 live at the same address as in 2002. The majority of those who moved between 2002 and 2017 did that once (85%). Around 14% moved twice, and 1,5% moved three times between 2002 and 2017. Furthermore, the majority (60%) moved quite recently (between 2011 and 2017). The relatively low level of residential mobility is also reflected in the average duration of residence at the current address in 2017, which amounts to 32 years (median 36). However, if we exclude those who moved, the average duration of residence even increases towards 44 years (median 46). The average age at the year of the relocation was 80 years (median: 80). This is in line with the international literature, pointing to a low residential mobility at older age, but with a rebound around the age of 80 (Angelini & Laferrère, 2012). Considering the average age of a residential relocation, its not surprising that more than one third (36,4% - n=33641) of all older adults who moved between 2002 and 2017, moved into a a residential care setting. If we exclude those older adults that moved to a residential care setting, the average age of a residential relocation decreases towards 78 (median 78). Not only do the numbers point to a relatively low residential mobility, also the distance over which relocations take place is rather low. By including all residential relocations, the average distance over which a move took place is around 9 kilometers. However, the median is less than 2.5 kilometer. Two third of all movements even took place within the same municipality (average

distance: 1,7 km – median 1,2 km). Unfortunately we do not have the data to link these moving processes to the type of dwelling but at least it coincides with the massive building of apartments outside the cities, popping up in small city centers and even in village cores or along connecting roads in suburban areas (Vanneste et al., 2007).

The previous section already gave us a complex image of some who moved to a better location, while others did not. As explained in the methodology, the level of amenities and services for each locality is assumed to be the same in both 2002 and 2017. Therefore, an improved or deteriorated situation is always a consequence of a residential relocation. Figure 5 shows the share of older adults who live within 250 meters from a specific amenity or service. Thereby, we made a distinction between older adults who did not change their residential location between 2002 and 2017 (orange) and those who did. For those who moved, Figure 5 shows the situation before the relocation (blue) and after the relocation (grey). It becomes clear that those who moved, have the highest chance to live closer to amenities and services. More surprisingly, those who moved between 2002 and 2017, already lived closer to the selected facilities in 2002, compared to those who did not changed their residential location. To give an example, 36% of those who moved between 2002 and 2017 lived within 250 meters from a small grocery store in 2017, compared to 31% in 2002 among the same group. However, less than a quarter of those who did not move between 2002 and 2017, lived within 250 meters from a small grocery store.

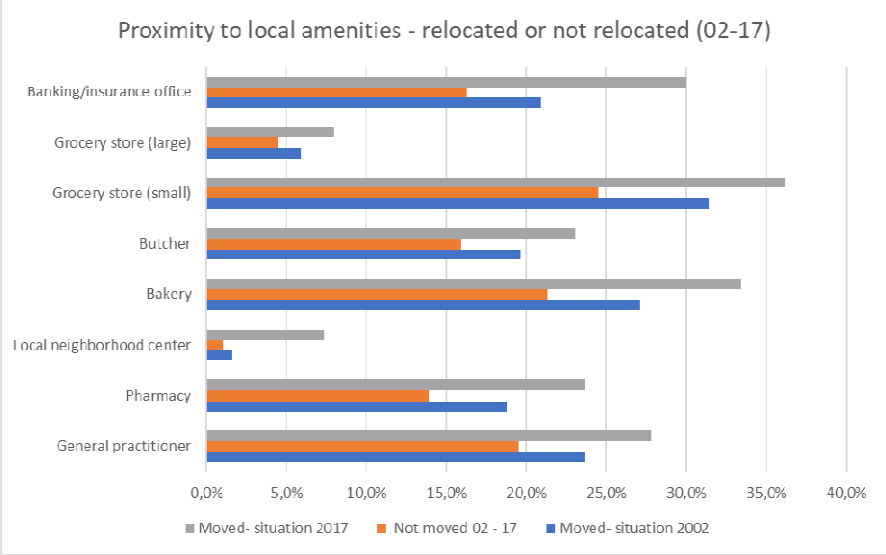

Figure 5: Share of older adults living within 250 meters from local amenities and resources, 2002 -2017. Source: data obtained from Statbel, VITO (based on VKBO), Agentschap Zorg en Gezondheid (2017)

From a policy perspective, this might not be good news since those people who might have a higher need to move to improve their environment in terms of facilities and services, do that the least. This might imply also that those who were better off already have a higher tendency to move, which has probably to do with the available financial resources to realize a relocation and/or because they are better informed about the possibilities and/or because they are more aware of the situation and challenges at older age and/or are more willing to take pro-active steps. While we do not have information about the income level, we can look into the educational level as proxy. When excluding those who moved to a residential care setting, we do see a small differences in the moving tendency, where higher educated older adults (24%), changed their residential location more, than those with a lower level of education (21%). However, also the distance to children (and the availability of the children to provide care and help), as well as the expectations from children regarding care can be factors of influence here. Someone who might not have children living close-by or cannot rely on informal care from a child might be more willing to move to a better equipped neighborhood, even when the neighborhood is already relatively well equipped, while someone who can rely on children living close by does not have (feel) the need to move to a better equipped neighborhood. Also daily habits and lifestyle routines can be a factor. Someone who is used to living close to facilities and services might be more willing to move closer to these facilities to sustain the existing lifestyle and routines when health issues arise or as a precautionary measure, while someone who is living relatively remote and is less used to living close to facilities and services might be less inclined to move as a precautionary measure

or when health issues arise, especially when the children live close(r) by and can provide help. Further research should therefore specifically take into account the distance to children for residential relocations.

To further check whether people moved to a better equipped neighborhood, we will differentiate by the type of location based on amenities and services, as discussed in the previous section. Table 6 shows that people who lived in a better location in 2002 had a higher chance to make a residential move, which is line with the findings from figure 5. More than one third of those living in an amenity-rich location in 2002 changed their residential location, compared to around a quarter of those living at a non-suitable location in 2002. However, this does say something about the place of origin but not on the destination; in other words, these data do not say anything about the type of location after a residential move. Of course it is possible that someone moved from an amenity-rich location (e.g. city center) towards a non-suitable location (e.g. rural area attractive for retirement), while it is also not sure whether those living in a non-suitable or minimum location moved to another (better) type of location.

Type of location (in 2002)	% moved (2002-2017)	% did not move (2002 – 2017)	Total
Not suitable	26,6% (17654)	73,4% (48833)	100%
Absolute minimum	27,7% (23672)	72,3% (61644)	100%
Moderately comfortable	30,2% (18627)	69,8% (43003)	100%
Suitable location	33,6% (12862)	66,4% (25392)	100%
Amenity-rich	38,2% (19865)	61,8% (32160)	100%
Total	30,5% (92680)	69,5% (211032)	100%

Table 6: Percentage of older adults that changed their residential location at least once between 2002 and 2017 differentiated by the type of location in 2002

However, table 7 shows the type of location in 2002 (before a residential relocation) and the type of location in 2017 (after a residential relocation) for all older adults that moved. It becomes clear that around 80% of those who lived in non-suitable conditions (and made a move), relocated towards a better equipped neigbhorhood. The same is true for 45% of those who moved and lived at a moderately comfortable location in 2002, and for 30% of those who moved and lived at a suitable location in 2002. However, this also means that a considerable share of older adults moved towards a location that is less equipped compared to the previous location. More than 60% of those who moved and lived at the best equipped locations in 2002 moved to a location that has less facilities and services (e.g. people who moved from a town or city center to a more rural area) in 2017. This percentage equals 47% for those who moved and lived at a suitable location in 2002, and 28% for those who moved and lived at a moderately comfortable location in 2002.

2002		2017					
		Not suitable	Absolute minimum	Moderately comfortable	Suitable	Amenity-rich	Total
	Not suitable	21,7% (3837)	19,1% (3372)	19,6% (3460)	16,4% (2887)	23,2% (4098)	100% (17654)
	Absolute minimum	9,3% (2199)	24,9% (5895)	22,5% (5335)	18,5% (4387)	24,7% (5856)	100% (23672)
	Moderately comfortable	7,9% (1476)	19,7% (36750	27,2% (5059)	19,2% (3584)	25,9% (4833)	100% (18627)
	Suitable location	7,0% (906)	17,8% (2287)	22,2% (2851)	22,9% (2945)	30,1% (3873)	100% (12862)
	Amenity-rich location	7,1% (1405)	15,1% (3005)	20,0% (3967)	19,1% (3795)	38,7% (7693)	100% (19865)
	Total	10,6% (9823)	19,7% (18234)	22,3% (20672)	19,0% (17598)	28,4% (26353)	100% (92680)

Table 7: Type of location before and after relocation for those older adults who moved, 2002 -2017

When we exclude those older adults who moved into a collective household (residential care setting) between 2002 and 2017, the numbers slightly change (Table 8). For example, from those who lived in 2002 at an amenity-rich location and moved (excl. to a collective household), around 47% remained living at an amenity-rich location. This is higher compared to the previous table which includes relocations into a collective household (39%). This also holds true for those who lived in 2002 at an absolute minimum, moderately comfortable or suitable location. More specifically, this means that the chance to move to an amenity-rich location is larger when someone does not move into a residential care setting. This might mean that a substantial share of older adults who remain living independently (or with children) and move, look for neighborhoods that are a better equipped.

Although it looks promising that around 72% of those who moved between 2002 and 2017, lived at least at a location that can be seen as moderately comfortable to age-in-place, this percentage drops to 54% if we also include those who did not move (see table 2). That means that those who move might indeed improve their situation, but that we should not turn a blind eye towards those who do not change their residential location,

since they live, in general, at less-equipped locations. Table 9 aggregates the previous 2 tables and shows that almost half of the older adults who changed their residential location between 2002 and 2017 and did not move into an residential care setting, relocated towards a better location. However, around a quarter moved to a location that is less equipped in terms of amenities and services that are relevant to age-in-place.

		2017					
		Not suitable	Absolute minimum	Moderately comfortable	Suitable	Amenity-rich	Total
2002	Not suitable	23,5% (2805)	16,2% (1938)	17,2% (2052)	15,6% (1863)	27,5% (3276)	100% (11934)
	Absolute minimum	8,9% (1358)	22,7% (3444)	20,5% (3112)	17,9% (2724)	30,0% (4551)	100% (15189)
	Moderately comfortable	7,4% (849)	17,0% (1962)	26,7% (3075)	18,1% (2091)	30,8% (3555)	100% (11532)
	Suitable location	6,0% (465)	14,5% (1130)	19,7% (1542)	24,0% (1876)	35,8% (2799)	100% (78120
	Amenity-rich location	6,0% (750)	12,0% (1507)	16,5% (2072)	18,4% (2305)	47,1% (5908)	100% (12542)
	Total	10,6% (6227)	16,9% (9981)	20,0% (11853)	18,4% (10859)	34,0% (20089)	100% (59009)

Table 8: Type of location before and after relocation for those older adults who moved, excluding those who moved into a collective household, 2002-2017

	Moved – excl. collective households	Moved in a collective household
Moved to a better location in terms of facilities and services	47,4% (27961)	40,8% (13712)
Moved to a similar location in terms of facilities and services	29,0% (17108)	24,7% (8315)
Moved to a less good location in terms of facilities and services	23,6% (13940)	34,5% (11614)
Total	100% (59009)	100% (33641)

Table 9: Change in location after a residential relocation between 2002 and 2017.

Until now we have investigated how a residential relocation affected the type of location (in terms of proximity to facilities and services). However, it would be interesting to have a deeper look into the spatial type. Table 10 indicates that 36,5% of those who lived in a city center in 2002 moved; a percentage that is higher compared to those who lived in any of the other spatial categories. That is interesting, especially considering that city centers already have the highest share of people living in close proximity to facilities and services, although it somehow confirms the pattern described earlier that those who move already seem to live in a neighborhood that is better equipped. Those who live in non-urban areas have the lowest chance of a residential relocation. Certainly many push and pull factors can be at stake. Proximity to amenities and services is only one of them, in addition to for example the distance to children, embeddedness in the neighhorhood, social networks and many more. Since we see a higher likelihood for relocations among those who live in urban areas, is its possible that the real estate market plays a role. While, overall, the level of homeownership is around 72 percent in Flanders, in urban areas this is much lower. In larger cities like Antwerp and Ghent the share of homeowners is 45%, in medium-sized cities around 60 -70% and in rural areas 80 percent or higher (Flanders, 2018). Since the rental market in general is less protective, compared to owning ones own dwelling, it might influence the likelihood to move. On the other hand it might also be easier to realize a relocation if living in a rental home.

Urban typology (2002)	% moved between 2002 and 2017	% no move between 2002 and 2017	total
City center	36,5% (26199)	63,5% (45497)	100% (71696)
Agglomeration	31,8% (15990)	68,2% (34283)	100% (50273)
Banlieue	28,5% (9721)	71,5% (24347)	100% (34068)
Commuting zone	28,0% (17447)	72,0% (44804)	100% (62251)
Non-urban (rural)	27,3% (23323)	72,7% (62101)	100% (85424)
Total	30,5% (92680)	69,5% (211032)	100% (303712)

Table 10: Urban typology (2002) and residential mobility

Table 11 shows that most people who moved to a better-equipped location between 2002 and 2017 did that within the same spatial type based on the degree of urbanization (physically and functionally). This is especially true for those who lived in a city center or rural area, 4 out of 5 persons moved to a better location within the same spatial type or category. The lowest percentages are found for those who lived in a banlieue (57%) or in the urban agglomeration (63%). This is not a surprise, banlieues are among the areas with the highest percentage of people living in badly equipped locations. Around 56 percent of those who changed their residential location and lived in a banlieue in 2002 moved to a better equipped location, which is the highest among all spatial types (not shown in table). Around one fifth of those who moved and lived in an agglomeration or banlieue relocated towards a city center. When we specifically look into those who moved

to a less-equipped location, we see a slightly more diverse patterns, and a lower tendency to move into city centers, with more people moving towards a commuting zone or rural area, for example to areas that might be attractive for retirement in terms of enjoying nature and quiet open space. In that case, we expect a trade-off with the rural atmosphere.

		2017					
		City center	Agglomeration	Banlieue	Commuting zone	Non-urban (rural)	Total
2002	City center	80,4% (4638)	6,9% (397)	4,4% (251)	4,4% (252)	4,0% (230)	100% (5768)
	Agglomeration	22,0% (1196)	63,1% (3436)	4,8% (259)	6,6% (362)	3,5% (192)	100% (5445)
	Banlieue	19,3% (678)	8,3% (291)	56,8% (1996)	9,5% (334)	6,1% (216)	100% (3515)
	Commuting zone	9,0% (501)	3,9% (216)	3,3% (185)	76,1% (4217)	7,7% (426)	100% (5545)
	Non-urban (rural)	8,2% (834)	2,0% (153)	1,8% (135)	4,9% (379)	83,1% (6387)	100% (7688)
	Total	27,3% (7647)	16,1% (4493)	10,1% (2826)	19,8% (5544)	26,6% (7451)	100% (27961)

Table 11 Spatial typology before (2002) and after (2017) a relocation for those older adults who moved to a better-equipped neighborhood between 2002 and 2017, excluding collective households

6 DISCUSSION AND CONCLUSION

The main goal of this paper was to get more insight in the suitability of the residential locations of older adults in terms of proximity to amenities and services in the framework of ageing-in-place and keeping a certain level of independence. Additionally, we wanted to investigate whether residential relocations at older age were directed towards better equipped neighborhoods. First of all, we would like to stress that our findings for Flanders show that only around 30% of all older adults in 2002 (65+) and 35% of all older adults (80+) in 2017 lived in neighborhoods that can be classified as amenity-rich or suitable locations to age in place, if dependent on the immediate surrouding. Around one fifth of all older adult live more than 1 kilometer away from any relevant amenity or services, while not necessarily living closer to their children. Regarding residential relocations the results show that the majority indeed moved to a better equipped neighborhood. However, those who moved, in general, lived already in better equipped neighborhoods, compared to those older adults that did not move between 2002 and 2017. This justifies a call for policy adjustments to pay more attention to the group that is not moving. This can be done through an awareness campaign for pro-active residential relocations and (financial) support for those relocations. This is especially true in the light of the Flemish housing policy that, for decades, stimulated homeownership (eventually with commuting) instead of dynamic relocations and residential mobility in the course of the life cycle (Meeus & De Decker, 2015). Without additional policy and support, it is likely that (health and well-being) differences between and inequalities among older adults who are moving and those who stay put are increasing rather than declining. Of course there are limitations and many aspects require additional research. First of all, while we focused on the “objective” proximity to amenties and services, having them nearby does not necessarily mean that they are the preferred one (e.g. a small convenient store versus a larger supermarket or a non-traditional or expensive store). Furthermore, a short distance does not imply that amenities or services are easily reachable, depending on for example the quality of the environment, such as sidewalks. In addition, even when no amenities and services are nearby, there might be home delivery services that might offset the lack of physical amenities and serives (e.g. Golant, 2019). However, also these services are not accessible everywhere to the same extent (Van Noort, 2018). While, in this contribution, the focus was on the impact of a residential move on the type of location in terms of amenities and services, in our future work we will look into the trade-off between the location and the distance to children in more detail (e.g. ranging from moving to a better location but further away from children till moving to a less equipped location but closer to the children) and the impact of personal characteristcs. It is known that children can influence the residential mobility of parents (Begley & Chan, 2022). Furthermore, linking residential relocations with the type of dwelling would be interesting, but currently there is no data available for this. In addition, extra attention should be paid to older adults without children, for whom the need to live in close proximity to amenities might be even more important. All in all, amenities and services are only one specific type of neighborhood resources; social networks, although very important for ageing-in-place, is another underresearched dimension (Pani-Harreman et al., 2020), which will be further expplored by the interviews we did in several Flemish municipalities.

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🏆 *reviewed paper*

Sustainable Operation of Digital Infrastructure in the Smart City: Practical Experience and Implications

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1 ABSTRACT

In the rapidly evolving landscape of smart cities, the emphasis on leveraging data for urban development often overshadows the critical consideration of how IoT infrastructure will be operated and how Internet of Things (IoT) data is captured. This paper explores the essential elements of establishing a robust IoT network and platform as the foundation for Urban Data Platforms, highlighting the challenges associated with the operation of IoT networks and shows implications for a future operation of the the Smart City infrastructure. The paper delves into practical experiences, shedding light on the intricacies of sustaining digital infrastructure in smart cities. Specifically, it addresses the balance between the functionalities of IoT networks, the scalability of hardware, and the efficient capture of real-time IoT data. The discussion encompasses technological, environmental, and socio-economic aspects, emphasizing the need for a holistic approach to ensure the longevity and sustainability of these digital ecosystems. It states the point that municipal utilities and service providers play a pivotal role as operators of the physical component of the digital infrastructure in this context. Their responsibilities extend beyond the provision of IoT networks to ensuring reliability, scalability, and security. The significance of these actors as cornerstones for the successful implementation and ongoing operation of digital infrastructures in urban. Through an integrative approach, municipal utilities can serve as critical partners in addressing the challenges of urbanization in the era of the Internet of Things, laying the foundation for sustainable, liveable cities.

Keywords: Sustainable Operation, IoT, Digital Infrastructure, LoRaWAN, Smart City

2 INTRODUCTION

The ongoing urbanization and respective population growth pose significant challenges to cities worldwide. The concepts of Smart Cities offer innovative solutions to address these challenges and enhance the quality of life for urban populations worldwide. Besides the global perspective, the topic of Smart Cities raises further importance also for German cities, especially in the light of an emerging federal funding perspective, such as Modellprojekte Smart Cities (MPSC)[1]. Besides the societal implications of Smart Cities, it is important to understand how they leverage the integration of Internet of Things (IoT) technologies to enable intelligent connectivity of urban infrastructures and services. IoT infrastructures, connecting a variety of sensors and devices, form the foundation upon which an efficient and sustainable Smart City can be built.

The rapid development of IoT technologies and the increasing availability of sensors have resulted in cities having a multitude of data sources, enabling comprehensive monitoring and analysis of urban processes. These data-driven insights present new opportunities to increase efficiency, reduce resource consumption, and enhance the quality of life in cities. This includes on the one-hand side “typically” know Smart City use cases for the city itself, use cases such as Smart Parking, Smart Waste, but also Smart Metering Usecases, which are often in the focus of the legal duties for public services. In the urban landscape, digital infrastructure stands as an indispensable pillar of municipal services and as backbone for many other digital services, akin to traditional physical infrastructures like roads and transportation systems. Just as roads are foundational to physical mobility, digital infrastructure is indispensable for the digital mobility and connectivity essential to modern urban living. As cities evolve in the face of demographic shifts, the seamless functioning of digital infrastructure becomes increasingly vital for ensuring the overall well-being of residents. Much like the reliability of roads and transportation networks, the effective operation of digital infrastructure is paramount to guaranteeing access to essential services, facilitating communication, and sustaining the overall liability of urban environments. In the context of demographic changes, where the

[1] Modellprojekte Smart Cities, BMWSB under https://www.bmwsb.bund.de/Webs/BMWSB/DE/themen/stadt-wohnen/staedtebau/smart-cities/smart-cities-node.html

composition and needs of city populations evolve, the role of digital infrastructure becomes even more pronounced.

In order to address these issues against the background of the maintenance of digital infrastrucutres, the paper is structured into five main sections. Firstly, it provides after the introduction an overview of the Components of the Digital Infrastructure, examining networking, hardware, and software systems pivotal in modern urban environments. Following this, leveraging Real-time-Data with IoT-Platforms as Foundation for Urban Data Platforms discusses the role of IoT platforms in collecting real-time data and establishing urban data platforms. Approaches in Operating a Digital Infrastructure then explores strategies for managing and operating digital infrastructures effectively. Maintaining a Smart City Infrastructure addresses challenges and strategies for sustaining smart city systems over time. Finally, the Conclusion summarizes key insights and findings, emphasizing the significance of digital infrastructure in smart city development and offering recommendations for future research and implementation.

3 COMPONENTS OF THE DIGITAL INFRASTRUCTURE

The focus of this scientific paper lies in the assessment of IoT and live sensor data as crucial part for a digital infrastructure. The development of live sensor data with IoT and it's potential for urban planning and management was seen and predicted already some decades ago even from a scientific perspective (WEISER, 1991) as well as in the popular discussion as "digital earth" (GORE, 1998). It was predicted, that the boundaries between sensors, computers, and mobile communication devices are increasingly disappearing and in addition to this, the ability to capture spatial data via spatial sensoring arises. These networked information systems are the first steps to a daily routine for the citizens, in which all entities of their environment are linked together in space and interact with each other. All of this produced and connected data will provide the way for the Internet of Things. Furthermore, this spatial relevant data could be made available for the public almost in real time (LIVE Singapore, 2011), which will make it possible, to gain very new insights about the functioning of a whole city. Even a decade ago, the potential use of live data was considered as foundation for a new "Science of Cities" (BATTY et al., 2012) and especially urban planners saw big potentials in making use of this data (EXNER, 2014). Besides the data processing capabilities, it is important to consider as well the necessary components of the layers of the digital infrastructure with its digital and physical components.

3.1 Interoperable layers of the digital Infrastructure for a smart city

Understanding digital infrastructure in layers is paramount for a comprehensive and effective approach to urban development. Each layer represents a distinct aspect of the complex digital ecosystem, from the deployment of sensors and communication networks to data management and the provision of smart applications. This layered perspective allows for a systematic and organized implementation, ensuring interoperability and scalability of the infrastructure.

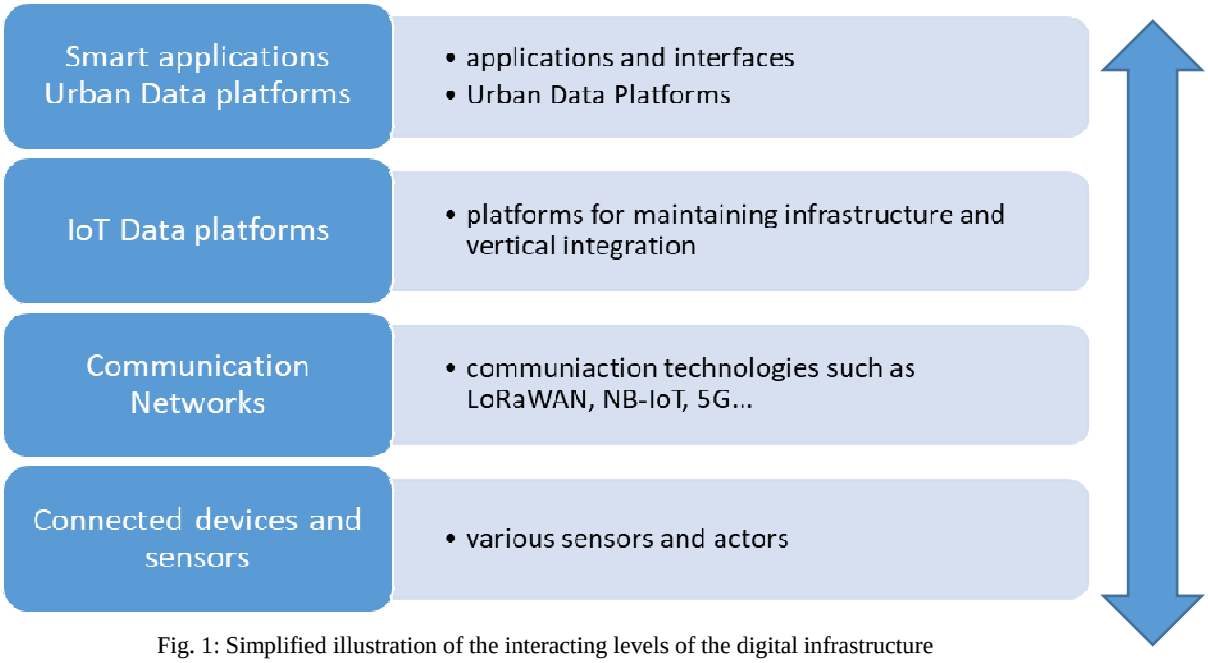

Fig. 1: Simplified illustration of the interacting levels of the digital infrastructure

By breaking down the digital framework into distinct layers, city planners and stakeholders from civil services can strategically address challenges at each level, optimizing resource allocation and facilitating the integration of new technologies. Moreover, a layered approach fosters a clearer understanding of the dependencies and interactions within the digital infrastructure, promoting resilience and adaptability in the face of technological advancements and evolving urban needs. In essence, viewing digital infrastructure in layers is fundamental for building a robust and sustainable foundation for smart cities, fostering innovation, efficiency, and an enhanced quality of life for urban residents. In addition, it is important to understand, that those layers work together modular, so that a different local authority could theoretically operate each element. This aspect is crucial to provide a long-term flexibility for the maintenance of the digital infrastructure. The respective layers are distinguished as follows:

3.1.1 Connected devices and sensors

In the era of smart cities, the seamless integration of connected devices and sensors into the urban fabric constitutes a cornerstone of the digital infrastructure. These devices, ranging from Internet of Things (IoT) sensors to advanced monitoring systems, form a sophisticated network that fosters real-time data collection, analysis, and transmission. This interconnected IoT enables cities to optimize resource utilization, enhance public services, and improve overall urban sustainability. From smart metering, smart traffic management to intelligent waste disposal, the deployment of these devices not only enhances efficiency but also paves the way for data-driven decision-making. Technically, this includes sensors and with the use of bidirectional protocols actors as well.

3.1.2 Communication Networks

Within the digital infrastructure of smart cities, communication networks serve as a critical layer, providing the essential connectivity that facilitates seamless interaction among various components. Particularly significant in this context are besides tradional cabel-oriented methods especially wireless technologies like WIFI, 5G, Bluetooth etc. low-power networks such as LoRaWAN® (Long Range Wide Area Network), which play a pivotal role in enabling cost-effective and energy-efficient communication for a myriad of IoT devices. LoRaWAN® technology stands out for its ability to support long-range communication while minimizing power consumption, making it ideal for the extensive and diverse deployment of sensors and devices across urban landscapes. In the realm of smart cities, organizations and entities have the flexibility to either act as their own connectivity providers or leverage services from third-party network providers. This bidirectional protocol allows the roles of „sensors“ and „actors“ for a tailored approach to connectivity management, offering the adaptability required to address the specific needs and scale of smart city initiatives. Whether cities choose to establish and manage their network infrastructure or opt for external connectivity services, the overarching goal is to establish a robust communication framework that underpins the seamless functioning of the digital ecosystem, fostering innovation, efficiency, and ultimately contributing to the realization of a truly smart and connected urban environment.

3.1.3 IoT Platforms for Data Management and Analysis

IoT platforms are technology frameworks designed to manage and enable the Internet of Things (IoT) devices and sensors. These platforms such as ZENNER Element IoT or Siemens Mindsphere, Azure IoT, AWS IoT provide the foundational infrastructure for connecting, collecting, and processing data from a variety of IoT devices distributed throughout the city. IoT platforms focus on facilitating communication between devices, managing data flows, and often include features like device management, data analytics, and application development interfaces specific to IoT. At this level, the collection, storage, and analysis of vast amounts of data captured by connected devices take place. Besides its software components, the maintenance of an IoT-platform often contains also the management of their crucial element – the gateways and sensors to run the network itself. Advanced analysis tools and algorithms are deployed to extract meaningful insights. As a crucial component, IoT platforms provide the infrastructure to connect and manage the various sensors and devices across the city, especially in a vertical perspective from sensor to platform. They facilitate data integration and play a vital role in the interoperability of the entire system.

3.1.4 Connected Urban Data Platforms

Urban data platforms, the linchpin of smart city ecosystems, serve as one central component with a horizontal orientation seamlessly integrating diverse data sources into a unified framework from different use cases, sources and public authorities. Besides live IoT Data from respective platforms, they connect also domain wide different data sources including for instance 3D city models or static demographic data. These platforms, often enhancing vertical structures of IoT platforms, act as the nerve centre for data-driven decision-making and operational efficiency. By aggregating information from various smart city components, such as IoT sensors and infrastructure systems, urban data platforms enable real-time insights into urban dynamics. Their role extends to optimizing resource allocation, enhancing sustainability through efficient resource management, and ensuring privacy and security in handling sensitive data. Positioned at the intersection of technology and urban governance, these platforms play a pivotal role in creating connected, responsive, and sustainable urban environments, driving innovation and improving the quality of life for citizens.

3.1.5 Smart Applications and Services

These are the applications and services based on the collected and analysed data. Examples include smart traffic control, energy management, environmental monitoring, smart building technology, healthcare services, and more. They can be fully or partly included within the existing platforms, or act as standalone apps. Smart applications and services constitute the dynamic interface of a smart city's digital infrastructure, translating data into tangible benefits for its inhabitants. These applications leverage the information collected by connected devices and sensors to enhance urban living in multifaceted ways. The embraces typical dashboards (Smart City Dashboards, Flood prevention dashboards…e.g.) but also dedicated apps or integrations in intelligent transportation systems that optimize traffic for instance. These applications streamline daily operations, improve efficiency, and create a more responsive urban environment. The integration on in services based on artificial intelligence (AI) opens up total new possibilities, but as today, the biggest potential is often seen by intelligent data services and alarming in a first step and further AI-based approaches that are more sophisticated. Embracing these smart solutions not only elevates the quality of life for residents but also contributes to the overall resilience and sustainability of the city.

4 LEVERAGING REALTIME-DATA WITH IOT-PLATFORMS AS FOUNDATION FOR URBAN DATA PLATFORMS

In the context of smart cities, the integration of Internet of Things (IoT) infrastructures plays a pivotal role in gathering real-time data and instant insights of the urban area. These infrastructures encompass a network of interconnected devices and sensors embedded within urban environments as described in the previous point. This paragraph highlights the aspects regarding IoT-infrastructures as real time data providers for further platforms and reflects practical insights from municipalities in the light data gathering of smart metering.

4.1 IoT infrastructures as the backbone of a Smart city

The Internet of Things (IoT) infrastructures constitute the foundational framework of a smart city, facilitating the interconnection of sensors and devices throughout urban areas to continuously gather data. This data, sourced from the physical elements of the digital infrastructure, assumes a pivotal role in shaping the real-time dynamics of smart cities, as evidenced by initiatives such as the "Live Singapore" project at MIT in Boston more than a decade ago (MIT Senseable City Lab, 2011). This project illustrates how ongoing data collection empowers urban authorities to make informed, data-driven decisions aimed at optimizing the efficiency of urban services. Additionally, the increasing significance of digitalization and transition within the energy sector will play a critical role in the context of smart cities. In the urban energy and utilities sector, the deployment of smart metering systems, for instance, facilitates the optimization of energy consumption (including water, electricity, heat, and gas) and the effective integration of renewable energies, which is pivotal for the energy transition. Monitoring these aspects is crucial for energy accounting, compliance with legal requirements, and the efficiency monitoring of the respective network.

Today, popular Smart City use cases, such as environmental monitoring facilitated by IoT sensors, enable real-time assessment of air quality and water levels or facilitating early detection and mitigation of environmental pollution for instance. In essence, IoT infrastructures lay the groundwork for a smart and

interconnected urban environment, where data-driven applications contribute to sustainability, efficiency, and an enhanced quality of life for residents. IoT infrastructures establish the groundwork for urban data platforms that enable comprehensive analyses and data-driven decisions. An essential aspect of this is an cost-effective and flexible bidirectional Low Power data communication network such as LoRaWAN®. LoRaWAN® (Long Range Wide Area Network) is an open wireless communication protocol that enables energy-efficient and cost-effective networking of IoT devices over long distances. It allows sensor data transmission over several kilometers, ensuring broad coverage throughout the city (see more under LORA ALLIANCE, 2024). One facilitating aspect of LoRaWAN® access is the existence of the supporting alliance. The LoRa Alliance's support ensures interoperability among various devices and networks, streamlining development and deployment processes. Furthermore, the Alliance's expansive ecosystem encompasses a wide array of stakeholders, including cities, utilities, device manufacturers, network operators, and solution providers, fostering innovation and driving adoption. This collaborative environment accelerates the growth of the LoRaWAN® ecosystem, providing a competitive advantage over other low-power communication networks by offering scalable, cost-effective solutions tailored to meet the evolving needs of IoT deployments worldwide. While its technical specifications are comparable to other low-power communication networks, the open standard, the possibility for self-hosting, and therefore the massive global ecosystem are crucial points leading to widespread acceptance worldwide and a diverse market of sensors in various classes and price segments. The networking of sensors via LoRaWAN® enables real-time monitoring of urban processes. Sensor data is recorded in real time and transmitted to central data platforms, where it is analysed and converted into meaningful information. These data platforms serve as a central interface for urban decision-makers to retrieve information, identify trends, and implement data-driven measures within a network of data platforms such as urban data platforms.

4.2 Insights from practise in the light of urban utilities

The insights presented in this work are gained from practical collaborations from the authors with city municipalities and utilites tasked with overseeing their municipal infrastruct. Through hands-on experience and close partnerships, the authors have gained valuable first-hand knowledge of the challenges and opportunities inherent in managing urban infrastructure, especially in the context of smart metering. “Smart metering is the computerised measurement, determination and control of energy consumption and supply. Companies and private households are equally relevant. Smart meters are intelligent, networked meters for resources and energy such as water, gas or electricity” (GABLER, 2024) and one of the key tasks of monitoring their utilities. They facilitate efficient resource management by providing accurate and timely information, leading to improved resource allocation, reduced waste, and cost savings. Furthermore, smart meters empower residents and businesses by offering detailed insights into their resource usage, encouraging responsible and sustainable practices. The integration of smart meters into the broader ecosystem of smart city technologies enhances grid management, supporting reliable energy distribution and the integration of renewable sources. Additionally, smart metering contributes to environmental sustainability by monitoring and reducing the city's environmental impact through optimized energy consumption. Smart metering stands out as the most important business case within the realm of smart city use cases due to its (at least in Germany) legal duties and it fundamental impact infrastructure optimization, which is also considered in various customers surveys regarding the importance of IoT infrastructures for smart cities. From a legal perspective, the importance of smart metering lies in its potential to enhance regulatory compliance, data security, and operational efficiency. In many countries, traditional methods of data gathering from meters, such as manual reading or drive-by-methods, are not only resource-intensive but also prone to errors and delays.

Smart metering, particularly when integrated with IoT technologies like LoRaWAN®, offers a more cost-effective and reliable alternative for data collection. By enabling automated, real-time monitoring and reporting of utility consumption, smart meters ensure greater accuracy and timeliness in data acquisition, thereby enhancing transparency and accountability in regulatory compliance. Additionally, the adoption of IoT-enabled smart metering infrastructures presents opportunities for synergies and cost savings across various sectors. Beyond their primary function of utility metering, these infrastructures can serve as a foundational layer for supporting additional IoT applications and use cases, such as environmental monitoring, traffic management, and public safety. By leveraging the existing infrastructure for multiple purposes, municipalities can maximize their return on investment and unlock new avenues for innovation

and efficiency in urban governance and service delivery. In the perspective of a city, it is always difficult to initially invest ressources (hardware, software and human ressources) run a usecase without a clear return of investment, if they will not have a dedicated funding. And if tender programs exist or a dedicated poilitical agenda, it has to be determined, that also the longterm operation is ensured as well. Therefore, from a legal standpoint, promoting the deployment of smart metering technologies with IoT integration not only ensures compliance with regulatory requirements but also fosters a more resilient and interconnected urban infrastructure ecosystem.

5 APPROACHES AND CHALLENGES IN OPERATING A DIGITAL INFRASTRUCTURE

The upcoming chapter embraces the aspects regarding running a digital infrastructure and its challenges that extend beyond the mere deployment of technology. Those insights were gained by the long-term work with many utilities and the corresponding exchange. The long-term operation adds another layer of complexity, necessitating strategies for sustainability and scalability to accommodate evolving needs and technological advancements. Moreover, maintaining different levels of maintenance across various components is another point, from routine upkeep to addressing unforeseen issues, demands robust strategies and resources. Emphasizing open data and open-source solutions presents additional challenges, including establishing protocols for data sharing and interoperability while balancing privacy and security concerns. Finally, the role of funding policies play a critical role, as securing adequate financial resources and establishing sustainable funding mechanisms are essential for the ongoing viability and growth of digital infrastructure initiatives.

5.1 Operation of physical components of the digital infrastructure

Cities are increasingly focusing on leveraging data for innovative solutions, emphasizing the "what can be done with data" aspect. Concurrently, public utilities traditionally concentrated on vertical issues, mainly generating data and maintaining network functionality. The value of the cost of data production by sensors in this light is often not fully envisaged. Besides gateway-related hardware services for instance, this embraces also battery replacements or sensor malfunction repairs. In the context of the sensor energy usage, the majority of sensors in the future will be wireless and low power networks will be play their important role. Of course, there are rapid developments in the light of sensors with energy harvesting methods, but this will not be the part for the majority of sensors. Every installed sensors needs respective resources (personal and financial) for its maintenance and it will be important to understand this, in order to prevent a scenario, that Mark Weiser's world of „Ubiquitous computing (and sensors)" turns into a world of „ubiquitous and continuous hardware maintenance" at the physical parts of the digital infrastructure. This shift underscores the necessity for flexible operational models, especially in the realm of efficient maintenance management. With the deployment of sensors in public spaces and the successful scaling of digital data processing, a notable challenge arises in the shortage of adequately trained personnel for maintaining these elements. Best practices for efficient maintenance management must address this human resource gap, emphasizing training programs and streamlined processes to ensure the proper care and functionality of the tactile elements, such as sensors. The implementation of these practices is crucial for sustaining the reliability and longevity of smart city initiatives.

In the light of these concepts, it has to be considered, that the involved partners are not only the communities but in some case the utilies directly. In Germany, municipal authorities often wield significant power and possess ample resources for managing essential infrastructure within their jurisdictions. However, it is not uncommon for these authorities to operate somewhat independently, sometimes existing outside direct city control. This unique legal landscape frequently raises questions surrounding the most effective maintenance models for critical infrastructure. With municipal authorities holding substantial sway and resources, but operating autonomously, determining responsibility and accountability for infrastructure upkeep can become complex. The decentralized nature of governance can lead to fragmented approaches to maintenance and decision-making, potentially affecting the efficiency and effectiveness of infrastructure management. As a result, navigating these legal dynamics becomes crucial for establishing sustainable and coordinated maintenance models that ensure the continued functionality and resilience of essential urban infrastructure in smart cities.

The long-term operation and maintenance of IoT infrastructures are decisive factors for the sustainable success of a smart city. Municipal utilities, as established public service providers with extensive experience in the utilities industry, are predestined for the role of operator of smart city infrastructures. Their close connection to the local community and their long-term commitment to the city make them trustworthy partners for the management and maintenance of digital infrastructure. The involvement of municipal utilities as operators of IoT infrastructures also offers further advantages. As they already have established communication and supply networks, they can utilise these infrastructures to support the data transmission of IoT sensors. Through this integration, smart city applications can be seamlessly integrated into existing systems, resulting in a more efficient and cost-effective implementation. Public utilities also take responsibility for data security and protecting the privacy of citizens. Careful management of the data collected is crucial to gaining citizens' trust in smart city initiatives and ensuring the smooth operation of infrastructures.

5.2 Different levels of maintenance

The operational models for digital infrastructure demand a high degree of flexibility to accommodate the inherently diverse nature of urban landscapes and the varied operational capacities of city authorities and service providers. This flexibility is particularly crucial when addressing the tangible components of the infrastructure. In the smart city landscape, delineating responsibilities for maintaining specific components of urban infrastructure is crucial for effective operation. Notably in Germany, a practical approach has emerged, where municipalities, aligning with their governance and data management expertise, often operate urban data platforms. In contrast, public services take charge of IoT platforms, leveraging their domain-specific knowledge to manage connected devices and ensure seamless integration. This division of responsibilities fosters a collaborative ecosystem, optimizing efficiency and resource utilization while ensuring that each entity capitalizes on its unique competencies in maintaining a cohesive and well-functioning smart city infrastructure. Additionally, when it comes to maintaining the physical aspects of the infrastructure, such as sensors, flexibility becomes paramount. The physical components of these components necessitates maintenance protocols that are responsive to diverse urban environments and adaptable to the distinct operational procedures of different city utilities. This also goes along with the issue of resilience. Resilience in the light of Smart Cities is considered as crucial in many perspectives (BBSR, 2023). Cities and municipalities face a dual challenge: on the one hand, they are required to pursue ambitious climate protection and sustainability goals to ensure sustainable urban development. On the other hand, they must cope with the already noticeable adverse effects of climate change and limit its consequential impacts. Against this background, it is important to make resilience tangible as the framework for sustainable urban development. It explains why it can be effective to engage more deeply with this concept in the development of smart city strategies. Resilience can be developed both as an independent element of integrated sustainable urban development and as a crosscutting, theme and management principle embedded in smart city strategies.

5.3 Requirements in the light of standards, open data, data interface and open source

In the context of Smart Cities, the significance of standards, interfaces, and APIs (Application Programming Interfaces) is crucial, but will not be the focus of this scientific paper, but shortly considered in their thematic connection. Standards provide a common framework ensuring interoperability and seamless integration among diverse open-source solutions and proprietary systems. They establish a shared language, enabling different components of the Smart City ecosystem to communicate effectively. Standards also promote scalability and sustainability, allowing for the expansion of Smart City infrastructure without compromising compatibility. Interfaces and APIs serve as connections through which various applications and systems can interact. By providing standardized interfaces, interfaces, and APIs facilitate the smooth exchange of data and functions, enabling a more interconnected and efficient urban environment. Open data and open-source initiatives play pivotal roles in shaping smart cities, offering distinct advantages and encountering unique challenges. On the positive side, open data fosters transparency, enabling citizens to access and utilize government-generated information for innovation and awareness. It encourages collaborative problem solving, fuelling the development of diverse and impactful applications. Similarly, open-source solutions promote flexibility and cost-effectiveness in smart city projects, allowing customization and collaboration among developers. However, challenges arise in terms of long-term maintenance and support. Open-source

projects may lack centralized governance, potentially leading to fragmented development or abandonment if they are not managed. This management has to be included, also from a business perspective. Ensuring ongoing support and updates may require dedicated resources from either the community or the adopting city. Balancing the advantages of community-driven innovation with the need for sustained maintenance remains a crucial consideration for the successful integration of open-source solutions in smart city environments. Hence, the role of standards and respective protocols is crucial, other questions regarding open source or commercial software has to be seen in the respective context.

5.4 Perspective of funding policies

The perspective of the federal funding policy has to be considered in this context, in addition, .The challenge faced by smart city funding policies is underscored by the call for a sustained, long-term perspective, surpassing the current emphasis on experimental projects. As mentioned in the beginning, the funding project of „Modellprojekte Smart Cities“ were an initial starting point to bring to topic of Smart Cities on most of the cities agenda. However, while recognizing the value of experimental designs for innovation, the realtion to crucial basic infrastructure such as networks, sensors, and communication systems is often not fully understood. Experimental projects can be faulted for operating in isolated locations and failing to encompass the entire urban population or infrastructure. Important is targeted funding policy prioritizing the development of a robust basic infrastructure, encompassing nationwide networks, energy-efficient buildings, and intelligent transport systems and not only lighthouses. This emphasis aims to facilitate seamless integration and scalability of diverse smart technologies. The goal is to bridge the gap between experimental designs and long-term urban development, thereby improving the quality of life and sustainability in German urban areas. This approach is positioned to be both compliant with the need for sustained, long-term development and flexible enough to adapt to the complex landscape of communities and civil services across Germany. However, the transferability is considered as important point, but the retrospective monitoring of such a program will show its implications for further funding activities.

5.5 Accountability of IoT service providers and defining the role of the service provider

In the context of smart cities, where IoT technologies are increasingly integrated into urban infrastructure, the principles of accountability and transparency are crucial to ensure that these advancements benefit citizens equitably and responsibly. City utilities emerge as pivotal players in this landscape due to their intimate understanding of local infrastructure and their direct engagement with the community. Through collaboration with IoT companies, city utilities can establish frameworks that prioritize accountability and transparency in the deployment and management of smart city technologies. This collaboration extends to addressing the complex issue of data ownership. As data generated by IoT devices becomes an invaluable asset in the development of smart cities, clarifying ownership rights is essential. City utilities, as custodians of public infrastructure and services, can advocate for data ownership models that prioritize the interests of citizens while also supporting innovation and economic development. By establishing clear guidelines and mechanisms for data governance, city utilities can ensure that data generated within the urban environment is ethically managed, securely stored, and leveraged for the collective benefit of the community. In this way, city utilities will play a pivotal role as trustful local actor in fostering public awareness and engagement regarding data ownership rights, empowering citizens to make informed decisions about their data and its use in the smart city ecosystem. In Germany, this goes along with the dual responsibility of Public Authortities. They must ensure the efficient provision of public services while also safeguarding the rights and well-being of individuals within their jurisdiction. This entails upholding high standards of service quality and accessibility, as well as protecting privacy, promoting equality, and upholding the rule of law. Through effective governance structures and transparency measures, they strive to fulfill these dual roles, also together in cooperation with companies from the private sector.

Similar to the water context where regulatory frameworks govern the operation of water distribution systems, it could be discussed, if the operation of IoT measurement points in smart cities may also benefit from a regulatory framework. Such a framework could provide guidelines and standards for data collection, usage, and privacy protection, ensuring that IoT devices deployed in urban environments adhere to ethical and legal principles. Moreover, a regulatory framework can promote interoperability among different IoT systems and facilitate data sharing between stakeholders, thereby maximizing the utility of smart city infrastructure. By establishing a regulatory framework for IoT measurement operations, city utilities and regulatory bodies can

mitigate potential risks associated with data misuse, privacy breaches, and technological malfunctions, while also fostering innovation and investment in the smart city ecosystem. Though, the disacvantages of a more formal and legally fixed IoT world, which was very dynamic by its orgigns, has to be discussed as well.

6 CONCLUSION

In summary, achieving successful and sustainable operation of IoT for a smart city infrastructure relies heavily on a comprehensive understanding and strategic management of various factors, particularly in comprehending the different layers of digital infrastructure and its physical components. A crucial aspect is ensuring transparency in data costs, both in granularity and quantity, alongside considerations of how this data can be processed by AI methods, for instance. Given that live IoT data serves as the backbone of a smart city, it is imperative for operators to grasp and efficiently manage these costs. Highlighting the scalability advantages inherent in digital environments becomes crucial for optimizing expenses over time.

Within the context of smart cities, defining the roles for maintaining urban infrastructure is essential for efficient operation. Germany plays a special role in the international contect, because the role of public utitilities (The “Stadtwerke”) as infrastrucutural provider is very strong and somehow unique in the international context. Thus, a noteworthy practice in Germany could be municipalities overseeing urban data platforms, leveraging their governance and data management expertise. Simultaneously, the public services handle IoT platforms, leveraging their domain-specific knowledge for seamless device integration and take care for their long-term maintenance with their respective ressources. This collaborative approach ensures optimal efficiency and resource utilization, with each entity focusing on its unique strengths to maintain a cohesive and effective smart city infrastructure. Furthermore, a key insight for long-term operators, such as municipal utilities, is the importance of prioritizing cost-effective base use cases. By strategically selecting foundational applications that strike a balance between efficiency and economic viability, such as smart metering, cities can ensure not only the functionality but also the longevity of their IoT infrastructure. This approach aligns with the overarching goal of smart cities to enhance urban processes and elevate the quality of life for citizens. Therefore, a forward-thinking perspective that integrates cost transparency and prioritizes economically viable use cases is paramount. Municipalities and operators must collaborate to establish a framework that not only meets the immediate needs of a smart city but also lays the groundwork for sustained, efficient, and resilient urban environments in the long run. In essence, the success of smart cities lies not only in the adoption of cutting-edge technologies but also in the astute management of resources and a commitment to sustainability at every level of infrastructure development and operation.

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Sustainable, Smart and Humane Cities: From Utopia to Reality

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1 ABSTRACT

This paper gathers the results of the research undertaken by the authors on the phenomenon of "New Cities" (NCs) conceived during the last thirty years, when urbanism began to be ruled by two basic principles: sustainability and smartness. Eighty case studies were selected from 38 countries on five continents in order to explore this dynamic and to answer the questions that triggered this research. What motivated NCs? What specific response did they adopt? What motivated their implementation or abandonment? Were they able to fulfil their own expectations?

Keywords: sustainability, reality, Utopia, Smart City, resilience

2 THE NEW CITIES: STRATEGIES, PLANNING AND OUTCOMES

2.1 A glance at history

Founding new cities is a strategy known since the earliest civilisations. The decision to build them depended on the coexistence of three conditions: a de facto power that would arrange their execution, sufficient technical knowledge to design and build urban structures, and sustained economic capacity over time to ensure their realisation. Their implantation in the territory depended on the strategic objectives expected from their implementation. From ancient civilisations until the Renaissance, the task of building new cities was functional: cities to centralise monarchic and religious power, bastides to defend frontiers. or colonies to consolidate conquered spaces. The baroque period introduced a new type of city intended for royal leisure, while the 19th century promoted a new urban model: industrial towns and planned bourgeois neighbourhoods. The 20th century introduced the functional city. Consolidating the urban planning techniques enabled to design the urban structures of the future, such as the British "New Towns" and the modernist cities of Brasilia, Chandigarh or Islamabad. The dynamic that transformed the model of the industrial city into the post-industrial one in the mid-20th century displaced comprehensive planning and master planning to give way to sectoral urban projects that were easy to adapt to the changing conditions of the environment. This growth model without general guidelines, included demolition and reconstruction and subsequently urban regeneration. It reached its limits towards the end of the century, when in 1992 the Rio de Janeiro Summit raised the urgency of redirecting the traditional urban model towards the paradigm of the "sustainable city." In parallel to this process, the new technologies developed in the 1990s found new fields of application in the urban domain, leading to the "smart city." Both concepts today underpin the urban planning proposals that public organisations and private companies use to implement the 21th century city, both by transforming existing cities and, especially, by creating new ones.

2.2 The rise of new cities in the world

The fever to build new cities during this period around the world has been astonishing. It was adopted as a panacea to solve the problems of current cities: overcrowding, pollution, traffic congestion, housing shortage, lack of green spaces, economic stagnation, social unrest, to name a few. Starting from scratch represented an extraordinary opportunity for agents with the capacity to do so. It encouraged governments and administrations to devise new policies and strategies, mobilised national and international capital towards new investment niches, and drove the creativity of planners to imagine new urban models. At present, some 200 new cities are either completely, being built or in the planning process. All of them are understood as a means to addressing different urban challenges. This massive-scale phenomenon began in the 1990s. However the realisation of these new cities had to overcome three successive, complex phases - initial decision, drafting the master plan and securing finance - on which the success or failure of the development companies depended,

3 METHODOLOGY

3.1 Literature review

"New Cities" (NCs) are a laboratory for urban analysis and provide an excellent research opportunity to recognise dominant trends in contemporary urban planning and design. Detecting these trends was the aim of our research. It is based on our initial observation of the astounding rise of NCs - visions as well as realisations - since the 1990s, especially in Asia and Africa. During our literature review we found very few academic papers on the NCs phenomenon and had to rely on documentation produced mainly by the protagonists of these NCs. From our literature research we compiled an empirical set of case studies on which we were able to access sufficient information in the public domain to create an analytical framework which would help understand their "raison d'être" as well as reasons for their success or failure. We aimed at a broad geography, but concentrated on Asia and Africa because NCs were most prominent and numerous there,

3.2 NCs typology development

Aware that all the protagonists were keen to present a promising future of their NCs, we discovered that the NCs concept was applied to different types of spatial developments, albeit all of them planned. For that reason, we aggregated this abundant, partial and dispersed information into a single analytical framework, a typology of NCs based on their stated objectives. Moreover, we also related their objectives to the challenges of five macro-categories of "sustainable" and "smart" planning: economic (growth and urbanisation process, project financing), social (societal and demographic structural changes, polarisation), environmental (climate change, greenwashing), technological (digitalisation, artificial intelligence) and political (governance, public and/or private development). When we developed the typology of NCs based on their stated purpose, self-declared objectives and development strategies, it became clear that some cities aimed at several, sometimes contradictory objectives in parallel. We refined the typology accordingly and used it in combination with the sustainable and smart city planning categories to structure our comparison between NCs which were totally or partially implemented and those remaining in the realm of visions and utopias. Predictably, information on financing was scarce, although lack of finance seemed the primary reason for NCs not to be realised.

3.3 Analysis

From the proposals of NCs and their results in practice and by using our two lines of analysis we explored which NCs and why they would lead to concrete implementation or result in ghost cities. We also were able to explore to what extent the techniques used in the conception of these urban experiences have responded to the challenges of planning over the last 30 years and how the utopian designs may influence trends in the urbanism of ideas

4 NCS: SOME INITIAL ISSUES

4.1 What are "New Cities"?

There is no universal definition for the NCs concept, as it refers both to independent urban entities, built from scratch, and to special districts located in the urban fabric of existing cities or in complex metropolitan areas. Both types have master plans specifically designed to meet the strategic objectives of their managers.

4.2 Spatial-temporal distribution

The analysis of the spatial-temporal evolution reveals the interest of different countries in addressing the construction of NCs to solve urban problems of various kinds. Most NCs are concentrated in East and West Asia, with a particular predominance in China, together with Kuwait, Japan, Saudi Arabia, India, the United Arab Emirates and Oman. This is due to their dynamic and prolonged double-digit economic growth resting on exports to Western markets and related rapid urbanisation, especially in Asia, led by China and followed by India later. The situation in Africa is equally notable, albeit with a smaller number of NCs than in Asia. Their prime purpose was to absorb the growing population and rural to urban migration rather than growing economy. Nevertheless, the experiences of Nigeria and Kenya are standing out. The participation of the Americas is scarce, although greater than in North America and Europe or Oceania, where the construction of NCs is negligeable as their economies and cities were more mature and their population stable or even

shrinking. Russia's absence of NCs is more difficult to grasp as it has great development potential based on its rich resources. The starting dates of the projects reveal that the interest of local managers in building NCs began in East Asia in the 2000s and 2010s, with a significant increase between 2010 and 2020. In Africa the trend accelerated between 2010 and 2020, while in the Americas it was between 2010 and 2020, greater in recent years. Proposals of a forward-looking urban nature started to develop after 2015, with new contributions up to the present.

Origin and objectives of NCs

They are various, depending on the environmental conditions that gave rise to them, among them:

- solution of urgent urban problems: overcrowding, pollution, congestion, housing shortages,
- expansion of informal settlements, effects of climate change
- strategies to boost the development of national and regional economies
- internationalisation of the image of countries as economically sustainable and technologically advanced
- real estate developments for business purposes and gated communities.

4.3 Project management

Project management of NCs is undertaken by specific protagonists, according to their own operational characteristics, and is essentially driven by funding.

- categories of protagonists: public - national and regional governments; private – developers,
- real estate companies, technology companies, design companies, rich individuals
- financing: national and foreign capital (notably Chinese, Arab, etc.)
- design of the master plan: national and international consultants specialised in this type of urban
- operations, depending on the type of NC, the size of the project and the number of projected inhabitants
- type of management: top-down, without citizen participation and, in many cases, with processes of eradication of the resident population in the planned development locations.

4.4 Budgets

The key issue for NCs is their financing in view of their extraordinary costs. Although this information is not always available, these values vary widely depending on the scale and characteristics of the project, exceeding billions of dollars in some cases, such as the New Administrative Capital in Egypt, Nurkent in Kazakhstan or Xiongan in China. Most are in excess of millions of dollars, with few projects below this amount, such as Diamniadio Lake City in Senegal, Trans Ganga High-tech City or Dholera Smart City in India. The costs of master plans have a diverse impact on the overall budget, depending on whether they are designed by renowned national or foreign teams.

4.5 Types of NCs

There is no single typology of NCs, given the variety of origins and objectives that drove the urban development proposals. The characteristics of the cases analysed enable us to distinguish between two basic types of NCs: the operational ones - designed to be built in specific spaces according to specific objectives - and the prospective ones, designed to respond to the urban challenges of the future. Some of these NCs are encompassing several categories and many of them claim to be 'smart' and/or 'ecological'.

Operational NCs: according to the global functions that gave rise to the NCs, it is possible to classify them into the following categories:

- Capital NCs, national and regional: the decision to build them responds to the interests of the
- government in power, whether authoritarian or democratic
- Business NCs: urban districts developed mainly by technology companies in existing cities,
- understood as laboratories to verify the application of their own technologies in urban space

- Productive NCs: aimed at regenerating regional economies, globalising national economies and
- attracting investors, set up in areas with more flexible administrative and fiscal systems than in the
- rest of the country
- Real estate NCs: urban developments designed to provide housing and land for all types of activities,
- generally promoted by private companies
- Green NC: projects designed in response to the implementation of specific environmental policies
- aimed at improving the quality of the environment.

Prospective NCs: urban projects designed to solve future challenges – some of them ongoing – are grouped into three generic types:

- Floating cities: in response to the risks arising from rising sea levels
- Techno-futuristic cities: interested in the application of new technologies in the urban environment
- Virtual cities: installed at the interface between the real and virtual worlds.

5 CASE STUDIES: CRITICAL ANALYSIS OF 80 SELECTED

5.1 Operational NCs

5.1.1 National and regional capitals

Regardless of the type of government and the socio-economic situation in the country, the decision to found a new capital city is an eminently political event that embodies the ambitions of its rulers. Malaysia's constitutional monarchy decided in 1995 to build Putrajaya (350,000 pop) as the administrative and judicial capital even though Kuala Lumpur retained its role as the official and legislative capital. Conceived as Asia's first smart city, its development slowed down after the 1998 economic crisis. Myanmar's military dictatorship decided in 2000 to build a new capital in the interior of the country to remove the remnants of Rangoon's colonial past. Naypyidaw (1 million pop), fully developed, is a ghost City, devoid of inhabitants and activities due to its isolation, lack of public transport and high housing and living costs. The same fate befell Amaravati (3.5 million pop), the new capital of the state of Andhra Pradesh in southeast India, whose development, started in 2014, stalled due to the pandemic and lack of funding. Today it is a ghost City with a few government buildings constructed. This is not the case of Egypt's New Administrative Capital (6.5 million pop), promoted by the government in 2015 as the icon of the 'New Republic of Egypt 2030' despite its sky-high costs and the country's deep economic crisis. Partially developed, the settlement of the inhabitants is slowing down due to high housing costs. In 2017 the president of Equatorial Guinea, in power for more than 44 years, decided to build Olaya City of Peace (60,000 pop) in the interior of the country in order to reduce the effects of political instability in Malabo. The fall in the price of petrol stalled the project, which is now barely developed. Faced with the unstoppable collapse of Jakarta, in 2029 the Indonesian government decided to build a new capital Nusantara (1.9 million pop). Located in the middle of the Borneo jungle, the financial collapse of the project seems imminent due to the lack of incentives promised to foreign investors by the current president and the end of his mandate.

Regarding regional capitals, in 2006 the Indonesian government decided to create Dompak (500,000 pop), the new capital of the Riau Islands province. Located in a Special Economic Zone and close to a polluting bauxite mine, the new city barely developed, slowed down by a high-profile corruption scandal and its irreversible environmental damage. Kilamba New City (500,000 pop) was designed in 2008 as the capital of the newly created municipality of Belas, Angola. Despite its advanced state of construction, it failed to attract inhabitants due to a lack of social housing and public transport, turning it into a ghost city. Meanwhile, the creation in 2018 of the New Capital of Ahal Province (70,000 pop), with no final name yet, was a decision of Turkmenistan's authoritarian president. The idea of building the country's first smart city is an ambitious project that began its first phase of development in 2021 despite the country's depressed economic situation.

5.1.2 Business NCs

NCs promoted by companies as experimental laboratories have similar characteristics. Fujisawa Sustainable Smart City (3,000 pop) is an experimental, smart and sustainable district built by Panasonic in 2008 in the Japanese city of the same name. The first of three planned neighbourhoods have been built, forming homogeneous communities belonging to the same technological environment. Also in Japan, Toyota built Woven City (initial 2,000 pop) in 2021 in the city of Susono, designed according to 16 criteria: community, personal mobility, autonomous vehicles, robotics, smart housing, artificial intelligence, service mobility, multigenerational housing, nature, health, hydrogen energy, academic research, cooperation between industries and smart construction. In contrast to the small scale of the Japanese cases, the Chinese communications corporation Tencent planned Net City (80,000 pop) in 2019 within the city of Shenzhen, designed to function as a place of work, residence and social interaction for the workers of Tencent's many companies. It is at the master plan stage and its design responds to government guidelines to respect the spirit of the environment and highlight Chinese characteristics.

5.1.3 Productive NCs

The objectives that drove the creation of these NCs are multiple, although the weight of certain goals allows for a generic aggregation into three sub-groups.

Regeneration and globalisation of national and regional economies: Cyberjaya (140,000 pop) was a pioneering case aimed at revitalising the national economy and transforming it for the digital age. Conceived in 1997 as the centre of Malaysia's "Multimedia Super Corridor", home to leading technology companies, it accommodates foreign staff, but housing remains inaccessible to the local habitants. The city of Songdo (300,000 pop), promoted in South Korea in 2000, was conceived as an alternative international business centre to Seoul and one of the largest public-private real estate developments in the world. However, the attraction of businesses and people was not as expected, as it remains sparsely populated. In contrast, Lingang New City (800,000 pop), a satellite city of Shanghai created in 2003 to support the new port of Yangshan, progressed according to plan.

Examples in Africa are significant. In Kenya, the 2008 development of Tatu City (80,000 pop) into a Free Economic Zone had the dual objective of attracting international business and decongesting Nairobi by capturing the growing national middle class. Its development has been slowed by legal and financial scandals and ownership disputes. Nigeria promoted two NCs for this purpose. Eko Atlantic City (250,000 pop) on an artificial island off Lagos in 2009, to attract big business, train local labour and relocate some of the inhabitants from the sinking capital. Partially developed, it aspires to become a commercial, financial, residential and tourist centre for the region's elites. The Enyimba Economic City (1.5 million pop), located in a Special Economic Zone in 2018, was intended to transform the country into a manufacturing and industrial power. Scheduled to be developed by 2023, it risks stalling as it is unable to secure funding. In Nigeria, Alaro City (30,000 pop) is a mixed industrial and logistics development implemented in 2019 in a Free Trade Zone with the aim of attracting digital businesses and high-income inhabitants. Its development is in its infancy. In Kenya, Konza Technopolis (180,000 pop) was conceived in 2008 as an epicentre of technological innovation for Africa's growing start-up industry. After navigating a heavy bureaucratic burden, only the first phase was launched.

The trade opportunities generated by the Chinese Belt and Road Initiative of a new Silk Road was launched in 2013 to improve connectivity and cooperation on a transcontinental scale, favoured the creation of NCs. The Chinese city of Ordos Kangbashi (1 million pop) was conceived in 2001 as a new economic hub in Mongolia to connect the Silk Road. Built in less than 10 years, it is sparsely populated and is the world's largest ghost city. Nurkent (110,000 pop), in Kazakhstan, started development in 2017 in the Special Economic Zone opposite Ordos Kangbashi but has seen little development. The Colombo City Port project, launched in 2016, aims to be a regional business centre and key hub for the Belt and Road initiative. Located in a Special Enterprise Zone on reclaimed port land, it is scheduled for completion in 2041. In India, Dholera Smart City (200,000 pop) was the first smart city and the largest urban development in the country. Included in the Delhi-Mumbai Industrial Corridor Special Investment Region since 2008, the first phase is being implemented.

Diversification of the economy: The King Abdullah Economic City project (2 million pop), designed in 2005 in the province of Mecca, Saudi Arabia, is an initiative to diversify the oil-based economy. It offers an

attractive environment for foreign investment and pilgrims, and is committed to leisure and entertainment. Development is well below the initial grand proposals. Qiddiyah City, 40 km from Riyadh, was designed in 2019 according to the Saudi Vision 2030 as an entertainment mega-project aimed at diversifying the country's income. In the same vein as Oman has promoted the construction of several NCs. Duqm New City (250,000 pop), near Muscat, was planned in 2018 in a Special Economic Zone. Given its strategic position on the Maritime Silk Road it operates as the China-Oman Industrial Park, including residential and commercial development and is under construction. Khazaen Economic City, planned in 2019 as Oman's first dry port, is the result of the Sultanate's largest public-private partnership to attract new investment and is under initial development. The Yiti Sustainable City (10,000 pop) was planned in 2022 to develop the country's tourism. Seventy-five per cent has been built and it is expected to be completed by 2025. In Ecuador, the Yachay City of Knowledge project (120,000 pop) was a presidential initiative launched in 2014 to build the country's first planned city, centred on a university and specialised industries. Highly politicised, the project was cancelled in 2023 after the change of government.

Model NCs projects: In Japan, the Kashiwa-No-Ha Smart City project (26,000 pop), managed since 2005 by the Urban Design Centre Kashiwa, comprises universities, local authorities and various public and private entities. It enabled the consolidation of a technologically advanced space adapted to different lifestyles, generations and uses. With totally opposite characteristics, the Amhara Model Town in Ethiopia was an experimental project initiated in 2010 by Swiss and Ethiopian architects and urban planners to provide housing and infrastructure for rural migrants to urban centres. Partially developed, it did not attract the expected number of inhabitants. Trans Ganga Hightech City was a 2014 proposal by the state of Uttar Pradesh (India) to create an Industrial Model Township, aimed at attracting investment, made up of productive, residential and commercial sectors, but remains in the pipeline. The Rublyovo-Arkhangelskoye city/district (66,500 pop) was designed in 2016 to decompress Moscow. Located in the outer Kunstsevo district, it was conceived as an International Financial Centre and a benchmark of best practice for the real estate market but remains in the pipeline. In Oman, Sultan Haitham City (100,000 pop) was officially inaugurated in 2023 as a new smart and sustainable district in line with the sultanate's Vision 2040. The aim is to launch similar projects in the Sultanate in the future, but it has not been developed. The Xiongan project (25 million pop) was launched in 2017 by the Chinese government to create a new district between Beijing, Tianjin and Hebei. With an area of 2,000 km2, encompassing more than 60 rural villages, it aims to become the most technologically advanced, best connected and environmentally sustainable city in all of China, targeting the strong domestic market and aiming to consolidate the high-end socialist market economy and is under development. Chengdu Future City, designed in 2021 according to the concept of a "living university", is a project that responds to China's interest in promoting academic education and high-tech industry in high-quality clusters.

5.1.4 Real estate NCs

They constitute the largest number of cases, as the "New City" concept provides private developers with a vision of an urban future in which it is worth living. Given the variety of objectives, the generic classification comprises five sub-types.

Capital city decongestion In 2013 the Emirates promoted the Dubai Sustainable City (2,700 pop), a small mixed residential and business green experiment developed by a private company to meet Dubai's needs is completed. The situation is not the same for Diamniadio Lake City (280,000 pop), a mega-project proposed by the Senegalese government in 2014 to decongest Dakar and promote the country's economic growth. Partially built, it is unaffordable for most Senegalese. In 2014, the Kuwaiti Public Authority for Housing Welfare initiated the Jaber Al Ahmad New City project (80,000 pop) through a tender open to private companies, driven by the growth of Kuwait City and now completed. In 2016, the same administration managed South Sabah Al-Ahmad City (280,000 pop), in the southern sub-region of the country, intended as a gateway to Saudi Arabia. Infrastructure works started in 2023.

Technologically advanced cities: Masdar City (50,000 pop) was the first green and smart city in the United Arab Emirates. Designed in 2006 as a model for humanity, it was a failed project, partially occupied and turned into a ghost city. The Line (9 million pop) is the most ambitious idea of the crown prince of Saudi Arabia. Conceived in 2011, the city is a single building, 170 km long, 200 m wide and more than 500 m

high, stretching from the Red Sea into the desert. Construction of the infrastructure began in 2023 but its realisation is in doubt.

Pastiche cities: Lavasa (300,000 pop) was the first private city built in the Western Ghats of India in the image of the Italian city of Portofino. Started in 2000 as a smart tourist destination, various circumstances turned it into a ghost town. Tianducheng (100,000 pop) is a huge luxury housing complex developed by a real estate company that emulates Paris. Built in 2007 in the suburbs of Hangzhou, China, it has become a ghost City, despite efforts to attract inhabitants and tourism. Shenyang State Guest Mansions (500,000 pop) is a ghost city located 400 km from Beijing. It was a baroque-style luxury housing development started in 2010 and stopped in 2012 due to lack of buyers.

Cities for urban elites: Sabah Al Ahmad Sea City (250,000 pop) was a pioneering project in Kuwait. Work began in 1993 to transform salt marshes into artificial islands and create 200 km of beaches. This massive infrastructure, consolidated and completed in 2021, created new development land. Rawabi (40,000 pop) is Palestine's first smart city, located outside Ramallah and developed by a private company since 2007, despite complex relations with Israel for its construction. An oasis of luxury in the West Bank, it is partially inhabited. Sharjah Sustainable City (5,000 pop) is the first high-end sustainable villa neighbourhood in the UAE, promoted in 2010 by the Sharjah Investment and Development Authority and a private developer. The last phase is under development and due for completion in 2024. Nkwashi satellite town (100,000 pop) is Zambia's largest private development, located in a Multi-Facility Economic Zone close to Lusaka. Projected in 2013 for the emerging middle class, it remains sparsely populated. In Bolivia, the Nueva Santa Cruz (370,000 pop) is a high-end real estate project developed by a Bolivian group since 2022 on the outskirts of the city of Santa Cruz with the assistance of Korean companies. It is under development. A private company was promoting Ho Chi Minh Global City in 2016, a sophisticated new district that will serve as a new "downtown" model for the Vietnamese city of the same name. In the pipeline, it is scheduled for completion in 2026. The proposal for Forest City (700,000 pop), a private city designed on four artificial islands to attract Malaysian residents from Singapore and Chinese real estate investors, was launched in 2016. Only partially developed, it failed to achieve its objectives and is becoming a ghost city.

Delocalised projects: The Parks, a smart and self-sufficient city project (150,000 pop) is a proposal developed for South Africa in 2022 by a private company based in Dubai, without a specific spatial location. The same company promoted a similar project Al Nama (44,000 pop) in 2016 for the city of Riyadh in Saudi Arabia. In 2022, it presented the XZero proposal (100,000 pop) for the southern part of Kuwait. Nexgen (35,000 pop) was proposed for the Eastern District of Cairo in 2023. All these proposals remain in the pipeline.

5.1.5 Green NCs

Designed to respond to sustainability, these NCs have sharply differentiated profiles. Tianjin Eco-City (350,000 pop) was launched in 2008 as a result of efforts by the Chinese and Singaporean governments to demonstrate the benefits of environmental policies in territories unsuitable for human habitation. With 75% of the area developed, it has failed to attract the expected population. The new city of Ouèdo (100,000 pop), in Benin, Africa, was designed in 2013 in response to the initiative to build social housing with sustainable criteria in the metropolitan area of Cotonou, its capital. Development started in 2019. New Clark City (1 million pop) was conceived in 2015 as an eco-city “twin” of Manila, Philippines. Based on climate and disaster resilience criteria, it aims to reduce congestion and pollution in the capital. Work started in 2019. Green City Kigali (150,000 pop) is a new neighbourhood planned for Kigali, Rwanda's capital, in 2017. The proposal with affordable and protected housing, supported by the Rwanda Green Fund and the Green Climate Fund among others is expected to start in 2024. The Orbit, a project to expand the agricultural city of Innisfil, Canada, was developed in 2017. A modern version of the garden city movement, it is in the pipeline, with the first phase planned for 2024.

5.2 Prospective NCs

5.2.1 Floating cities

Artisanopolis (1,000 - 2,000 pop) is a pioneering project of self-sufficient floating platforms, connected to each other and organised according to circular economy principles, devised in 2017 with support from the French Polynesian authorities and US scientific and engineering companies. Floating City (20,000 pop) is a

self-sufficient, flood-proof aquatic city designed in 2022 as a luxury holiday destination, with the collaboration of the Maldives government and the Dutch Docklands company. It is under development since 2022. Biodivercity, consisting of three islands (15,000 and 18,000 pop each) was designed in 2020 to create a “global destination” to facilitate sustainable economic and cultural growth and protect the biodiversity of Penang Island, Malaysia. It is in the pipeline. Dogen City (10,000 pop), a self-sufficient floating smart city project was designed in 2023 by a consortium bringing together industry, academia and government in Japan, scheduled to start in 2024. Oceanix Busan (12,000 pop) is a pilot project devised by a private company for the city of Busan, South Korea, in 2022 with the support of UN-Habitat and the Busan Government, planned to start between 2025 and 2028.

5.2.2 Techno-futuristic cities

Akon City (300,000 pop) is a futuristic city promoted by a rap singer and inspired by the film Black Panther. Designed in 2018, it is geared towards tourism, leisure and culture. The government of Senegal donated the land for its construction, 100 kilometres from Dakar. With no development whatsoever, the city was symbolically launched in 2023. Telosa (5 million pop) is the proposal of an American billionaire to be developed somewhere unspecified in the US desert (Nevada, Utah, Idaho, Arizona or Texas). Based on a reformed version of capitalism and 19th century communal living, the project adopts the principles of the Garden City and the 15-minute city. Smart Forest City (130,000 pop) was conceived in 2019 for Cancun, Mexico, as a carbon-absorbing botanical garden within a contemporary city. The project proposes an urban ecosystem where nature and the city intertwine to act as a single organism.

5.2.3 Virtual cities

Liberland Metaverse, 2022 (Metaverse), a proposal for the Free Republic of Liberland, is a "cyber-urban" city, a digital "twin" of the real world where virtual citizens - avatars - carry out activities without territorial limitations. This idea was also adopted by Tuvalu, a small Pacific Island nation composed of three coral islands and six atolls with a total area of less than 26 km2, threatened by rising sea levels. The project was announced at COP27 in November 2022.

6 PLANNING AND DESIGN CRITERIA

Drawing up NCs master plans offers their designers the opportunity to translate the spatial conditions of “sustainable” and “smart” cities into the urban structures requested by their protagonists. The planning proposals of the eighty NCs case studies respond, to a greater or lesser extent, to providing answers to the following principles: cities being respectful of nature, attentive to social experience, economically advantageous, and assisted by new technologies to facilitate the functioning of day-to-day urban living. What lessons can be drawn from these experiences? What planning and design criteria were used in the drafting of the master plans. Which ones are inherited from functionalism? What are the new ones?

6.1 Traditional criteria

Orthogonality: Most NCs master plans have adopted orthogonal layouts, in some cses adapted to the topography of geographical features of the site. The internal urban organisation based on main roads and secondary streets of different categories continuous to offer maximum functionalism and safety. Other cases (Putrajaya, Amaravati, Nusantara, Kilamba, Yiti, Rawabi, Biodiversity, Chengdu, Qiddiya, Lavasa, Rublyovo-Arkhangelskoye, The Parks, Xzero, Alnama Smart City, Nexgen, South Sabah Al-Ahmad City, Kashiwa-No-Ha Smart City) adopted organic forms, while only a few pursued new radial structures (Lingang New City, The Orbit).

Functional zoning: Except in newly created urban districts owing to their small scale, the urban structures of NCs maintain functional zoning separated into specific uses: central areas for representative, administrative and symbolic functions, secondary centres for specific activities, residential districts with various typologies around activity sub-centres, and peripheral industrial spaces. High densities are dominant and urban infrastructures are designed as a complete range of social facilities providing a wide variety of services. Open spaces maintain their prominence and consume large amounts of land

Symbolism: Metaphors and features of indigenous architecture are used in the design of some NCs, such as the grand civic architecture of Naypyidaw, the 13 squares of Amaravati representing the 13 districts of

Andhra Pradesh, the references to Mughal design and Islamic ornamentation of Putrajaya, those of Indonesian culture of Nusantara, or the traditional village features of Chengdu Future City.

6.2 Recent criteria

Inclusion of nature: Including nature in the urban fabric is the dominant aspect of all projects. It aims at multiple functions: reducing temperature, capturing carbon, enriching biodiversity, managing water and flood control, and increasing the quality of life of the inhabitants. The incorporation of green corridors as structuring elements of the city, instead of the traditional vehicular circulation axes, is a constant in the design of the master plans (Amaravati, Putrajaya, The Parks, Yiti Sustainable City, Ho Chi Minh Global City, Kashiwa-No-Ha Smart City, Net City, Tianjin Eco-City). Including green networks of different types of open spaces is a widespread practice: gardens for food production (Putrajaya, Yiti Sustainable City, Kashiwa-No-Ha Smart City, Xiongan, New Clark City), peripheral arable land (Amaravati), greenhouses (Sharjah Sustainable City, Masdar) or endemic vegetation and hydroponics (Woven City). In some cases, green design prevails throughout the project (The Parks, Xzero, Alnama Smart City, Nexgen

Diversity of neighbourhoods: Although diverse criteria characterise NCs designs at local level, they tend to be multifunctional, pedestrian-centred and organised around community centres that encourage community life based on the 15-minute-city principle (Amaravati, Sultan Haitham City, Lavasa). The quality of the urban landscape is enhanced by the quality of urban design. Sometimes this is achieved by reinforcing the prominence of buildings, as suggested by iconographic proposals in master plans, some also with strong scenographic character (Rublyovo-Arkhangelskoye, Qiddiya, Chengdu, Diamniadio Lake City, Nusantara, Net City).

Climate change mitigation and adaptation: The reduction of energy consumption and CO2 emissions is the declared aim of many NCs. Measures taken in this regard relate to the passive retrofitting of buildings and public spaces, focusing on the layout of buildings, the use of appropriate building materials and the treatment of trees (Masdar, Nusantara, Dubai Sustainable City, Sharjah Sustainable City, Alaro City, Tianjin Eco-City).

New technologies: A main feature of NCs is to apply advanced technologies to the functioning and management of urban services. The inclusion of digital technology, AI, IoT, Big Data and other technological tools enables the monitoring of urban performance, ranging from household and community energy consumption, to mass surveillance for security purposes. Other applications are the provision of charging points for electric vehicles, waste collection and the robotisation of different activities (Fujisawa, Woven City, Net City, The Line.

Social infrastructure: The location of key social facilities is decisive for the internal organisation of some NCs, in particular for university campuses (Nkwashi, Yachay City of Knowledge, business parks and train stations The Orbit, Chengdu Future City).

7 MAIN CRITICISMS

The principles of “sustainable’ and “smart” cities are disrupted in numerous NCs case studies and for various reasons.

Environmental sustainability: The selection of unsuitable sites is the main aspect violating environmental sustainability principles. They are causing severe environmental impacts, such as locating in a swampy area with water scarcity and air and water pollution (Xiongan), massive earthworks for the construction of NCs necessitating intense deforestation with serious effects on biodiversity (Olaya, Lavasa, Nusantara); land reclamation from the sea altering the maritime environment, as well as impairing traditional local fishing (Dompak, Colombo City Port, Eko Atlantic City, Forest City). At the urban design level, lack of passive microclimatic solutions - wide streets, large squares, shading trees, adequate building materials, instead of glass and steel - hamper the increase of environmental quality.

Social sustainability: Adverse collateral effects on the local population undermine the principle of social sustainability, especially when building NCs involves displacement and relocation of the local population, or inadequate economic compensation to landowners (Naypyidaw, Dompak, Xiongan, Trans Ganga Hightech City, Duqm). Lack of social housing and high costs of private housing, aimed in general at the emerging middle classes or high-income groups, are generating significant social bias (Nkwashi, Kilamba, Sharjah

Sustainable City, Forest City, Kilamba New City, Konza Technopolis, Ciberjaya, Eko Atlantic City). Other exclusionary aspects are the construction of safe enclaves to reduce the threat of natural hazards, which are leaving a large part of the population unprotected (Nusantara, Eko Atlantic City). The construction of urban islands is also alien to the context in which they are inserted, as they are occupied by a homogeneous influx of inhabitants whose economic or social profiles differ widely from those of local inhabitants. Other alienating causes are non-inclusive urban designs (Putrajaya, Nusantara). introducing cultural identities alien to the local culture (Lavasa, Tianducheng, Shenyang State Guest Mansions, Rawabi, Ho Chi Minh Global City).

Economic sustainability: Lack of attractiveness prevents companies from relocating their activities in these NCs, as well as their high cost of technological infrastructures, which in some cases limits their realisation, and makes them economically unsustainable (Masdar, Tianducheng, Songdo). Moreover, their smart city approach, which incorporates various technologies based on massive processing of personal data, raises concerns about both the lack of privacy and the limitation of randomness in everyday life (Fujisawa, Woven City, Net City).

8 SUCCESS OR FAILURE FACTORS

Moving from theory to reality is an immense challenge for NCs and, in most cases, there are inevitable changes to their original plans. The slow process of developing NCs over time encourages these changes. Most of the case studies are still at various stages of the development process, a few have failed and some remain ghost cities, waiting to attract funding, people and activities.

The variables that facilitate, slow down or discourage the development of these projects are wide-ranging, with political support being a crucial factor in initiating projects, seeking funding and giving continuity to the process. Securing continued funding is crucial, as the high cost of these ventures is a major burden on the finances of countries, especially those facing economic crises or high levels of poverty. Investors are extremely concerned about political changes, legal problems and bureaucracy that hinders development processes and encourages corruption, as well as lack of credibility of local officials and private developers. They are interested in well-managed projects that are able to adapt to economic stresses and unforeseen problems.

Ambitious or extravagant projects raise many doubts about their viability, both because of technological limitations and possible financing problems. Isolated and badly connected to the rest of the cities, with poor employment prospects and high cost of living, create low expectations for investing in their development. In addition, property speculation - a recurrent fact - does little to help the development of NCs, as it favours price increases and limits the effective occupation of housing and other premises.

NCs begin their development with great effort, dependent on the slow relocation of governmental headquarters, public companies, the establishment of productive activities and the arrival of a population whose presence is the only guarantee of a future dynamic urban life.

9 CONCLUSIONS

9.1 Why NCs and why build them?

The design of today's NCs does not differ substantially from those built before 1990. The British New Towns (1940-1970) were the first references of the current NC phenomenon, conceived to respond to the social demands of the post-war period: to provide housing -by building social housing, and jobs - by facilitating the establishment of companies. The promotion of welfare through the construction of new cities had a direct impact on the type of work of planners and architects and especially their willingness to incorporate innovative techniques into the traditional master plans.

The construction of today's NCs, understood as engines of economic growth, emerged after the crisis of the 1980s, when the process of globalisation shifted the focus of attention first to Asia and the Middle East and then to Africa. Although there are no precise figures, more than 150 NCs are in operation in more than 40 countries, costing billions of dollars and justified as the ideal means to meet the urban challenges of the 21st century. The demands of growing hyper-capitalism and the search for new investment niches to house global corporate wealth were determining factors in the evolution of this process.

Equally important was the role of the international consultants commissioned to design the new urban models for NCs, who initially transferred the latest trends of Western planning and design – a combination of environmental principles (eco-cities) and technological solutions (smart cities) - to the East.

However, the spectacular and iconic images of NCs, designed as showcases of the global economy, took on a completely different trajectory from these initial planning and design criteria. Adopted mainly in the developing countries, they no longer played the same role as in the West and were not given adequate attention for the designs of NCs, which may explain why most NCs are elitist, commercial, superficial and even politically incorrect in Western eyes (1).

9.2 NCs in Asia and Africa

The rise of NCs was spurred both by rapid population growth and urbanisation in these continents and by the need to diversify and stimulate national economies. In general, NCs are conceived as multi-purpose, self-contained and self-sufficient cities, combining spaces for innovation and knowledge with speculative residential and commercial developments for a certain type of inhabitants.

Asian NCs are mostly economic products aimed at promoting the internationalisation of the country where they are located, giving an image of modernity to attract companies and capital, and satisfy the needs of the growing local middle and upper classes, with little impact on low-income groups who, excluded from the process by their ethnicity, religion or socio-economic status, continue to live in the old cities in the same conditions as always (2).

African NCs have more modest objectives, although they were designed as centres for technology, innovation and knowledge for national and regional economic development. The underlying idea is to attract high-tech industries, start-ups and universities, along with a residential and commercial development base that does not address the housing needs of Africa's impoverished urban centres (3).

Although the NCs phenomenon has developed exponentially over the last three decades, a significant number of them are still in the pipeline, facing uncertain futures. Among those that have materialised, many have not progressed beyond the initial phases, and very few have completed the planned development. The attraction of population and activities is a slow and difficult process, which has left many ghost cities in its wake.

The NC urban project and its management

Unlike Europe, where the economic and demographic recession of the 1980s impeded the construction of NCs, displaced the use of master plans and adopted urban acupuncture as a way of intervening in existing cities on an ad hoc basis, Asian and African NCs opted to build from scratch. Devising new settlements on a ‘tabula rasa’ is easy, providing the problems of existing, congested and polluted cities and megacities are removed

Bar exceptional cases, NCs were planned without any public participation. This approach, in which the developer makes decisions, defines priorities, takes on responsibilities and determines the financing model devalues the role of planning instruments, and by excluding citizens and decentralised bodies generates social tensions, grey areas in governance and very limited ownership of the project by users (4).

Master plans, whether conceived by public agencies or private developers, have to be alluring to attract investors and residents. State intervention in the construction of NCs is a key factor, as it can promote institutional changes, remove or relax existing regulations, change planning regulations, create tax exemption zones or coercively expropriate large tracts of land (5). The results of such deregulation have a wide range of adverse consequences, such as social exclusion and increased inequality, spatial fragmentation, environmental degradation and even threats to democratic processes (6).

Displacements of local populations were a common practice given the need to achieve a ‘tabula rasa’. The forced sale of rural properties in the name of economic development, without fair remuneration and without assured relocation of their owners, had significant social and even environmental consequences, as traditional land uses disappeared. Most of the time, displaced people were not able to seek justice, due to lack of laws protecting customary or informal property rights (7).

Once the initial difficulties were overcome, the movement of international capital towards NCs projects, notably Chinese, Russian and Arab. was extraordinary. Controlling the use of such investment is key to

avoiding corruption, bearing in mind that NCs management is in the hands of private companies, bespoke public agencies, public-private partnerships, or similar whose organisational models, financial tools and relations between agents - client, investor, developer, designer, builder and end user - are constantly changing. Africa's special social circumstances called for funding aligned with poverty eradication. In some cases, sought from organisations, such as the World Bank, UN-Habitat or development corporations from different countries.

An accepted fact is the socio-spatial segregation inherent in NCs, owing to their function as socially homogenous and closed enclaves for the middle and upper classes who have the purchasing capacity to enjoy high quality housing and well-designed urban spaces. This elitist factor distances NCs from one of the main principles of the sustainable city: social heterogeneity.

Last but not least, the massive use of technologies and smart devices aimed at improving the living conditions of NCs inhabitants has meant permanent surveillance of their activities and massive use of their personal data. The impact of such intrusion into the privacy of people's lives is the main dilemma of smart cities, and the alienation generated by these technologies prevents smart cities from enjoying the natural dynamism of traditional cities, built over time and to the rhythm of local history and culture.

10 REFERENCES

EXPLANATORY NOTE. Data used towards this paper are drawn from countless sources of information freely available on the Internet. They include promotional documentation issued by NCs protagonists, as well as a variety of other references on the case studies in particular and on the NCs phenomenon in general. Too numerous for all to be quoted only the academic articles are cited.

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🏆 *reviewed paper*

Synergizing BIM, Digital Twin, and XR: An Approach for Real-Time Building Analysis and Enhanced Laboratory Management

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1 ABSTRACT

The emerging shift in the use of innovative and digital technologies in the architecture, engineering, and construction (AEC) industry promises an opportunity to create consistent, system-intelligent buildings that provide a reliable source of all relevant information about the building for maintenance, technical management, or decision-making processes in real time. For this vision, the integration of Building Information Modeling (BIM), Digital Twins (DTs), Internet of Things (IoT), and Extended Reality (XR) in the context of operative building management and research data utilization within laboratory environments proves to be essential to leverage smart buildings as an enabling pillar of a smart city. This paper presents a novel approach for in situ generation of 3D building models from point cloud scans, providing a valid real-time representation of the existing state of a building. This process significantly enhances the accuracy and utility of BIM in existing structures where pre-existing digital models are not available.

Further, we delve into the enrichment of these models with IoT sensors strategically placed within building spaces. These sensors are designed to monitor indoor air quality and occupancy through motion detection, offering a comprehensive view of the buildings environmental and usage patterns. This real-time data, coupled with the integration of laboratory measurement devices and their DT, facilitates a more dynamic and responsive building management system. In contrast to the majority of current approaches and concepts in research, the resulting models emphasize live data and, in accordance with the definition of a DTs, reflect the state and feedback representation bidirectionally into the virtual space and vice versa back into the physical space substantiated by XR technologies.

An essential component of our methodology is the development of interfaces between the BIM model and DTs of laboratory equipment, seamlessly incorporating the generated research data into the building model. This integration ensures that the BIM model remains a central, up-to-date repository of both physical and functional characteristics of the building and its contents.

Moreover, we introduce a collaborative XR environment, enabling transdisciplinary teams to interact with and analyze the BIM model and associated data in a highly immersive and intuitive manner. This XR platform fosters enhanced collaboration and decision-making, bridging the gap between various stakeholders involved in building management and research. The approach demonstrates the potential of utilizing advanced technologies to not only create these models post-construction but also to continuously update and enrich them with operational data, thereby facilitating a more efficient and informed management process. Providing standardized interfaces to smart buildings with the BIM and IoT information obtained through the concepts presented can also create added value in the context of smart cities through clusters of such smart buildings.

This paper contributes to the field by showcasing how the synergy of BIM, DTs, IoT, and XR can revolutionize building management and Research Data Management (RDM), offering a comprehensive, real-time, and interactive digital representation of physical spaces and their operational dynamics.

Keywords: Research Data Management, Extended Reality, Building Information Modelling, Augmented Reality, Digital Twin

2 INTRODUCTION

The integration of modern disruptive technologies as a part of the digital transformation holds potential in all areas of public life, industry, as well as within research institutions (Lehmann et al. 2023). It opens up a broad variety of opportunities to enhance the efficiency and functionality of buildings especially under the premises of Construction 4.0 as well as laboratory environments. Static building information or Building Information Modeling (BIM) data can be combined with real-time Internet of Things (IoT) data in order to create contextualized information. Such Digital Twins (DTs) as comprehensive digital representations with live IoT data can enrich BIM data with operational data and thus go beyond historical or static data compilations (Nasaruddin et al. 2018; Temidayo et al. 2018). Extended Reality (XR) and Virtual Reality (VR) devices can process this contextualized DT information for different operators and serve as a basis for collaboration or improvement. In addition, the information provided by the DTs can also be utilized as a partial blueprint for smart city objects (Coupry et al. 2021).

Central to this approach is the idea of creating a comprehensive digital representation of buildings through the generation of 3D models from point clouds, serving as a foundation for optimizing building operations. These models can not only depict physical space but also integrate various digital experimental setups and laboratory equipment used in research institutions. By utilizing these digital models, various use cases can be derived to make building and laboratory operations more efficient. Another aspect is the direct integration of Research Data Management (RDM) into the digital model. By linking research data to the corresponding building and laboratory areas, researchers can seamlessly access the required data and utilize it for further knowledge generation. To harness the maximum potential from the various technologies, a holistic interaction approach is required. This involves not only the use of point clouds and IoT devices but also the development of a XR application that enable users to interact with the DT.

This paper deals with the question of how buildings and laboratories at research institutions can be intelligently geared with research equipment, users such as employees or students in the context of barely accessible BIM data and integrated RDM. Therefore, the state-of-the-art is assessed based on current literature in section 3 followed by the introduction of the detailed use case in section 4. Section 5 presents the overall concept, followed the implementation in section 6. After a qualitative validation and discussion in section 7, section 8 summarizes and provides future work prospects.

3 RELATED WORK

Digital Transformation has become an indispensable premise across a broad range of fields and industries in order to exploit its ingrained advantages of increasing efficiency and effectiveness in operations. (Aghimien et al. 2018) The approach of using innovative digital technologies in the architecture, engineering, and construction (AEC) industry has been solidified as ‘Construction 4.0’ as an integral pillar of the fourth industrial revolution. (Temidayo et al. 2018) As part of these efforts, BIM is emerging as a pivotal methodology for the digital representation of physical and functional building information over the entire life cycle. The emerging transformation implies a shift away from the traditional design paradigm towards the goal of creating consistent, system-intelligent buildings that provide a reliable source of all relevant information about the building for maintenance, technical management, or decision-making processes in real time (Hotový 2018). Nevertheless, the realization of BIM is associated with certain obstacles by which the methodologies potential remains limited. Current applications notably show constraints in terms of scalability, interoperability, or remote support, preventing the information from being used reliably by the user (Liu et al. 2023) and further restricts interaction between different fields. The main benefits of implementing BIM range from efficient monitoring, administration, planning and maintenance of ongoing operations and assets to improved information sharing and visualization (Lu et al. 2019).

To make this vision a reality, various IoT technologies such as DTs or XR applications enable the successful implementation of BIM aiming to consolidate various information streams and integrate further knowledge

into building process workflows (Liu et al. 2023). In addition to the mere representation of the physical counterpart, further intelligence can be incorporated into the digital representation through functionalities such as simulation systems, machine learning algorithms or visuality through XR technologies in order to provide the potential to achieve added value.

The DT builds on the premise that all systems can be portrayed in dual form by having a digital representation in addition to their physical counterpart. Descriptions, measurement data or changes in the state of the physical system are reflected in the virtual space and vice versa. The DT has its roots in product lifecycle management, where the original objective was to depict the entire lifecycle of the physical counterpart in a virtual representation (Grieves, 2023). Enabling a holistic representation of the physical counterpart depends on the data that is continuously collected and stored in the virtual entity. The reliable availability of this data is the prerequisite for creating added value and knowledge generation for a sustainable research landscape. In the context of RDM, data must be handled according to the following principles: Findable, Accessible, Interoperable, and Reusable (FAIR) (Mons 2018). These can be explicitly implemented in particular through the use of DT approaches in laboratory environments (Lehmann et al. 2023). Also, the DT facilitates interoperability between different software and platform entities through a single channel which is a fundamental characteristic of the BIM concept and crucial to the success of a project (Flamini et al. 2022).

Shirowzhan et al. (Shirowzhan et al. 2022) explore the application of selective technologies for enhancing urban intelligence within smart cities through the utilization of DTs. Their research emphasizes the role of virtual representation technologies in supporting decision-making processes. Smart cities and the associated efforts to transform the AEC industry can therefore be improved by utilizing these opportunities. Accordingly, the concept of the DT appears to be an ideal approach when realizing BIM in the modern construction industry. Various approaches using the DT concept in BIM can be found in the literature. Nasaruddin et al. (Nasaruddin et al. 2018) describe a rudimentary concept framework to utilize DTs for BIM. Sensor data for predictive maintenance use cases, optimization and visualization are considered. Flamini et al. (Flamini et al. 2022) develop the dynamic DT, which serves as the foundation for the plant's SCADA functionalities to manage the technical functions. In combination with XR technologies, the supervision and technical management is ensured over the entire life cycle. Building on this, Loggia et al. (Loggia et al. 2024) and Flamini et al. (Flamini et al. 2022) have extended the original approach to ensure electrical safety in order to offer rapid intervention in the event of an error. Despite the fact that the concept of DTs appears to be beneficial for the realization of BIM, achieving full implementation still seems to be challenging. Deng et al. (Deng et al. 2021) define various research gaps and characteristics for modern implementations of BIM DTs. Among other things, further research is needed regarding real-time monitoring, IoT data collection, performance prediction of building condition through simulations, machine learning techniques or the ability to facilitate decision-making through the integration of humans into the control loop.

The use of 3D scanning technology in the context of creating point clouds for BIM and XR concepts is a useful application that is based on the reconstruction of real-world architectural environments and offers numerous advantages. These advantages manifest themselves in particular in the increase in efficiency digital reconstruction of existing environments while also increasing the precision of corresponding virtual representation (Coupry et al. 2021). A key aspect that emphasizes the use of point clouds is their ability to capture and document existing structures and environments with extreme precision. By capturing millions of points in a three-dimensional space, point clouds provide a highly accurate digital representation of the real world. Compared to traditional methods of manual surveying or the creation of 3D models through CAD design. The use of point clouds offers a significantly faster and more accurate way of capturing existing environments. The technology thus makes it possible to create previously non-existent digital representations of building (Dolhopolov et al. 2023). Liu et al. (Liu et al. 2021) review different applications of laser scanning in the context of the life cycle of buildings enabling BIM. For this purpose, they analyze the integration of BIM and 3D laser scanning in several domains, such as construction site safety, rescue after disaster, energy modeling or management. Mirzaei et al. (Mirzaei et al. 2022) use terrestrial laser scanners (TLS) to capture point clouds in order to generate geometric DTs of BIM structures. Using a deep neural network, structures are derived from the point clouds and then homogenized and enriched with semantic information. The resulting geometric DT is limited to updating BIM data or monitoring the health status of the building but does not integrate any operational real-time data. Bassier et al. (Bassier et al. 2015) describe

different types of laser scanners used in BIM scenarios. They distinguish between TLS, mobile laser scanners (MLS) and airborne laser scanners (ALS). Also advantages and disadvantages of each system are being discussed. Abreu et al. (Abreu et al. 2023) analyze different types of scan applications related to BIM. More precisely they review the differences of feature extraction algorithms in Scan-to-BIM and Scan-vs.-BIM. The two scenarios differ on the one hand in the creation of a digital image of existing building structures, while the other scenario deals with the comparison of existing 3D models with a scan. Kazhdan and Hoppe (Kazhdan & Hoppe 2013) deliver one of the most commonly used algorithms for modeling meshes based on point cloud. The 'screened poisson surface reconstruction' algorithm interpolates watertight surfaces based on point sets. Especially for modeling interior scans algorithm is often one of the best choices. Another decisive factor that supports the use of point clouds is their compatibility with various digital technologies, especially in the area of XR concepts. By integrating point clouds into XR applications such as VR and augmented reality (AR), users can enjoy realistic and immersive experiences in digital environments based on precise measurement data. This opens new possibilities for applications in areas such as architectural visualization, real estate development, virtual tours and simulations (Wu et al. 2023).

4 USE-CASE DESCRIPTION

Utilization and safe operation of research laboratories is a common challenge. The requirement to optimize the use of laboratory space without compromising on safety requires approaches to room monitoring. The use of fragile and vulnerable scanning systems depends on strict laboratory conditions. These systems must function accurately and reliably to provide valid data without compromising laboratory safety. The handling of hazardous materials and the use of lasers in research environments emphasize the importance of stringent safety measures. The ability to monitor and control experiments remotely offers flexibility but raises questions about safety. In particular, ensuring that no unauthorized individuals have access to the laboratories at any time while sensitive experiments are being performed is a top priority.

In addition, different measurement conditions and environmental factors make it difficult to carry out consistent and reproducible experiments. Adapting laboratory conditions to specific experimental demands requires precise control and monitoring systems. Safety precautions must be always maintained. The correlation of measurement data with environmental information presents a further challenge. Finally, the general handling, collaboration and management of experimental data requires an efficient data infrastructure.

These issues illustrate the complexity of modern laboratory operations and scientific processes in research institutions. It highlights the need for solutions to improve efficiency, security, and data management in these critical environments.

5 CONCEPTUAL APPROACH

Since the current state-of-the-art has been determined, the challenges described in the use case can be addressed in more detail and architectural approaches can be elaborated. Initially, these are presented for handling building management and RDM by combining XR, IoT and DT concepts. Therefore, various approaches proposed in the previous work are incorporated in order to meet current requirements. There are initially four relevant branches of work in architecture, which are finally consolidated into one main approach: The capture of 3D building data and derivation and creation of applicable models, the development of suitable IoT devices for monitoring and logging of room parameters, the setup of a suitable real-time framework for mapping, connecting and managing the DTs of the IoT and research items as well as the programming of a suitable XR application as a visualization and interaction interface to all available DTs.

Figure 1 shows the proposed architecture of the operational DT framework, which forms the center of the overall approach and unites all branches. It is divided into three areas: the Physical Twin Space, the Digital Twin Space and the Application Space which are further highlighted in the following.

The Physical Twin Space contains the physical devices which enable the later interaction within the XR environment. Those are named Physical Twins (PTs). A distinction between two types of devices is made in this space. The architecture separates IoT and Device PTs. The IoT PTs must be suitably equipped with appropriate sensors for recording the room parameters and a detector for sensing the presence of occupants. Sufficient robustness of the devices is a prerequisite. IoT PTs are designed to monitor and record

environmental parameters while Device PTs are used to conduct measurements, create research data, or regulate the environment. The Physical Twin Space in the architecture contains the PT n as a generic representation of other PTs that can be added in future extensions.

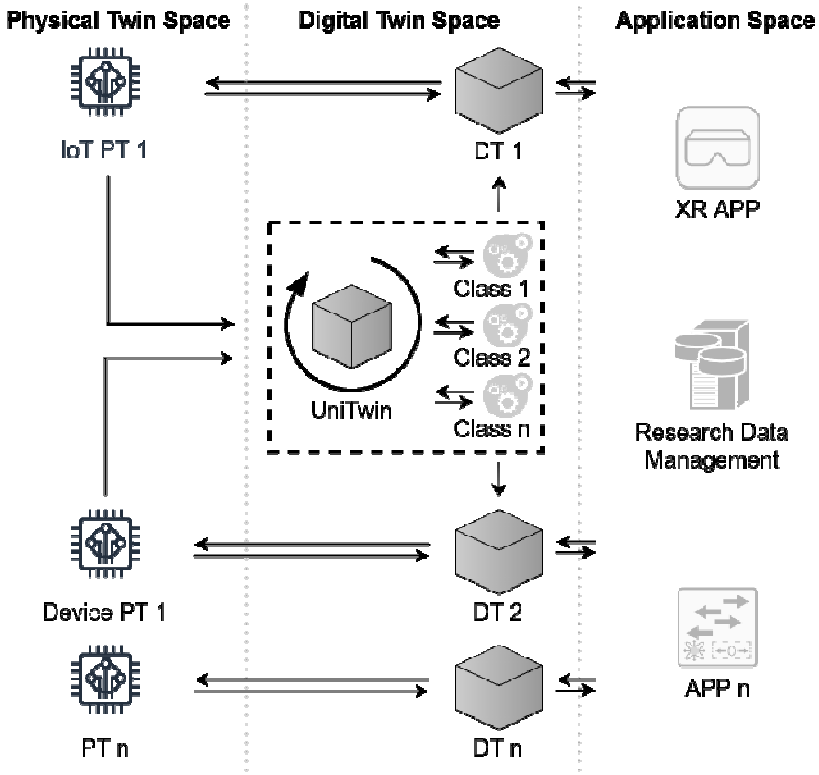

Fig. 1: Conceptual architecture for building management and research data management

Next to the Physical Twin Space the Digital Twin Space is located which acts as the architectures' middleware layer. For the provision of all DTs, a framework published in the previous work [Haeussermann et al. 2023] is utilized. It provides containerized modular DTs based on a given configuration. Therefore, the PTs send their configuration to the so-called Digital Twin Provisioning Service (DTPS). After receiving the configuration, the DTPS starts a so called UniTwin container for each PT. Those containers instantiate various class files depending on the configuration. Then the instantiated DTs establish a bidirectional connection to their associated PTs and connect to the applications or provide defined interfaces to the applications located in the Application Space.

The Application Space includes two key applications to cover the presented use case: the XR Application and the RDM Application. The XR application takes care of the interactions with the physical devices and is an enabler for all use cases such as remote experimentation, remote maintenance or room planning. It is primarily based on the appropriate volumetric scan of current 3D building data. The third element in the Application Space App n is a generic placeholder for any application to be added in the future. With the provided RDM application the DTs are enabled to store gathered data persistently and according to the FAIR criteria. The RDM in this approach highly relies on and integrates with the RDM infrastructure presented in the previous work [Lehmann et al. 2023].

6 IMPLEMENTATION

After outlining the general concepts and approaches, the four main branches within the implementation section are examined in more detail. First, the volumetric scan including the processing of the recorded data is considered. The practical structure of the IoT Device PTs must then be illustrated, followed by the introduction of the DT framework. The XR application forms the completion as the interaction interface of the entire work.

The adaptation of digitization in existing building structures requires the readiness of state-of-the-art 3D scanners, which are considered consolidated technologies. Within this range, divergent systems and methodologies manifest themselves, including Terrestrial Laser Scanners (TLS), Mobile Laser Scanners (MLS) and Airborne Laser Scanners (ALS). A NavVis VLX 3 scanner, which belongs to the MLS genre as a

prominent state-of-the-art technology example, was used in the current project. These instruments are characterized by a pronounced user-friendliness and enable the comprehensive mapping of building structures without the need for complex pre-planning and subsequent data merging. However, it should be noted that precision is reduced compared to terrestrial laser scanners and is limited to a few centimeters.

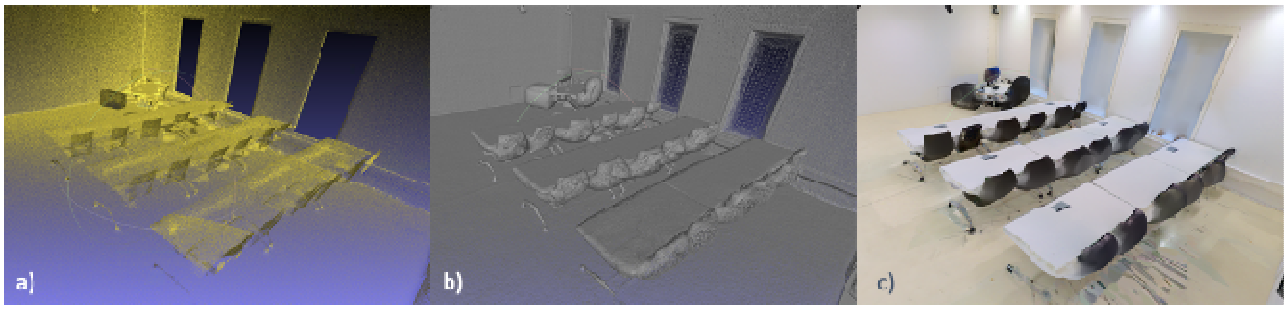

Fig. 2: Different processing steps of the point cloud. a) showing native point cloud without any processing steps b) wireframe of calculated mesh without textures and colors c) colored mesh.

The integration of the captured building into interactive XR scenarios as well as into the concept of the DT requires the transformation of the point cloud resulting from the scan into a mesh. The open-source software MeshLab is used for this purpose. It should be noted that several pre-processing steps are essential in order to eliminate error points (noise) and other anomalies in the point cloud (see Figure 2a). This can be realized by means of filtering or outlier detection. Furthermore, the calculation of normals is essential in order to determine the spatial orientation of the points, which is of fundamental importance for the subsequent mesh generation.

Once the point cloud has been pre-processed, the actual generation of the mesh can begin. For this purpose, the ‘Screened Poisson’ algorithm is recommended, which connects points with the same orientation based on the calculated normals and interpolates a continuous surface (see Figure 2b, 2c). Despite the interpolation, redundant surfaces can occur during the mesh calculation, which must be removed during post-processing. Surfaces can be selected and eliminated based on a defined edge length.

Due to the objective of this article to implement the generated point cloud on virtual reality headsets / Head Mounted Devices (HMDs) as well as on lightweight platforms such as standalone HMDs (e. g. VIVE XR Elite, Microsoft HoloLens 2) or tablets and smartphones, the native point cloud was initially used for the present use case to display the environment. Within the described application scenario, no interaction with the environment is planned for the time being, which is why the point cloud can be used instead of a mesh without further processing. This makes it possible to reduce one process step and the associated effort.

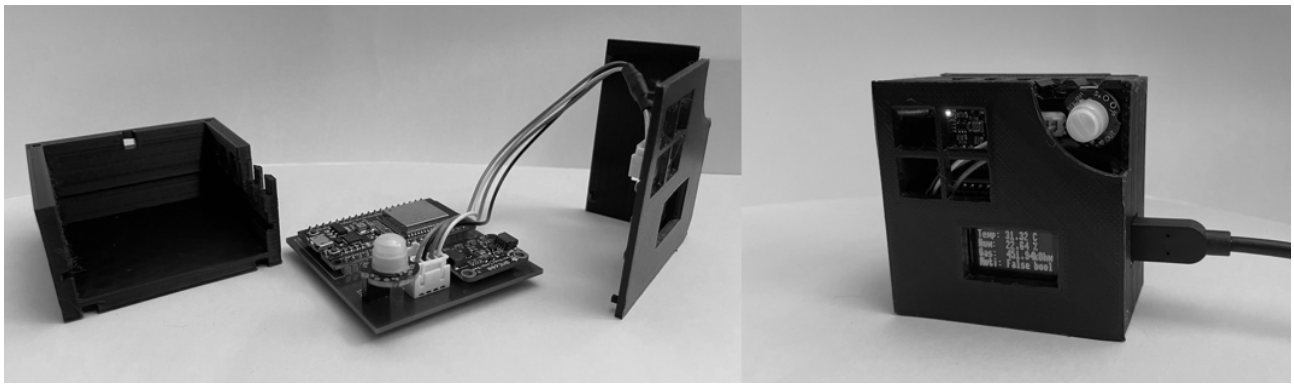

Fig. 3: Design of the IoT indoor air quality measuring device for detecting indoor air characteristics and room occupancy

According to Figure 3, an integrated measuring system was developed as an IoT device PT to measure the indoor air and presence parameters. The integrated NodeMCU microcontroller with ESP32 processor was selected as the basis for performance and cost reasons. One of the great advantages of the microcontroller is the direct integration of wireless communication such as WiFi or Bluetooth. To record the air values, a breakout board with the Bosch sensor BME 680 which detects relative humidity, barometric pressure, ambient temperature, and gas (VOC) was used. The passive infrared sensor SR602 was installed to detect movement within the dedicated supervision area. An OLED display also shows all measured values. The

display and the gas sensor are both connected via I2C. The microcontroller software is based on Micropython and opens an interface to the DT framework with the given components. In order to achieve sufficient robustness, a suitable printed circuit board was designed and produced as well as an adequate housing was designed and printed.

In the Physical Twin Spaces two PTs are implemented. As IoT PT 1 the described IoT measuring device is used to monitor environment parameters in order to provide insights about conditions from remote. For the Device PT 1 a Hyperspectral-Near Infrared (NIR)-Imager built at the research institute is utilized, to generate relevant research data. The NIR-Imager is driven by a LattePanda Delta 3 which provides a Flask-RESTful-API for the communication with the DTs. Both PTs are located in the same physical location and are enhanced with the ability to pass their configuration to the Digital Twin Space. The framework utilizes the containerization environment Docker and the images DTPS as well as UniTwin at a centralized server cluster at the research institute. The PTs from the Physical Twin Space provide their configuration to the DTPS via HTTP and are provided with a custom UniTwin container. After instantiation the UniTwin container represent the DTs. The DTs establish bidirectional connection to their associated PTs and to the applications in the Application Space. As outlined in the conceptual approach the RDM application is part of the presented RDM infrastructure. Therefore, it uses a combination of InfluxDB and Dataverse to provide the ability to store various kinds of data in FAIR manner. The open-source time series database InfluxDB is used to store discrete data points from the IoT PTs. Besides InfluxDB, Dataverse is used to store data which is not suitable for storing with InfluxDB like NIR-images generated by the Device PTs. Dataverse is an open-source application used to store research data in repositories while improving the publishing, citing as well as versioning of that data.

The operative procedure of its implementation is as follows. After the DTs are provided by the DTPS the IoT PT 1 transmits environment parameters to its DT. Those parameters include relative humidity, barometric pressure, ambient temperature, VOC, and motion inside the monitored area. The DT takes care of storing the Data in the InfluxDB and transferring it to the XR application. Thereby it enables monitoring the room remotely inside the XR application. Meanwhile, with the instantiation of its DT, the scanner is in standby mode and waits for commands. These commands can be given physically on the device or in the XR application and include the start and stop command for a scan as well as its reset. However, it must be emphasized that the DT with its access to all information has the ultimate decision on the execution. In the case the scanner is started manually the DT is informed about the intend to start a scan. To release the scanner for starting, the DT checks the state of movement monitored by the IoT PT 1 by requesting the state from the corresponding DT. If movement is present in the room the DTs aborts the start command in order to prevent harm for people inside the room. Otherwise, it approves the start and notifies the XR application about the new condition of the scanner. In case the scan is started via the XR application, the process is reversed. The XR application sends a start command to the DT which checks for movement with the IoT PTs DT. If movements are present in the room the DT cancels the start of the scanner. In the absence of movement, the DTs sends the start command to the scanner which begins to scan. The DT of the scanner also takes care of checking movements continuously while scanning with the measurement devices DT and immediately stops the scan if movement is detected.

In the final step, the XR application combines all the components described to interact with the overall system. It was developed with Unity 2021.3.22f1. This game engine allows the platform-independent creation of applications that work on various HMDs as well as in 2D environments. The system offers users the possibility to use XR applications on a variety of devices, from computers and mobile devices such as smartphones and tablets to immersive HMDs. These can be used either stand-alone or in combination with a workstation. By intelligently linking the game engine and third-party software, stationary VR systems such as powerwalls and CAVEs can also be used. These systems offer the advantage that, in contrast to HMDs, several people can participate in a session simultaneously and collaboratively. The developed solution enables flexible adaptation to different situations. For example, if the laboratory environment is not available, strict safety measures make its use difficult, or access is not possible due to security reasons, the previously created scan can be displayed. This facilitates orientation and enables a virtual tour of the laboratory without having to go to the site. In contrast, optical see-through HMDs or video pass-through HMDs offer the possibility to extend the current environment with virtual screens. These allow the display of current telemetry data of the desired physical device in real time.

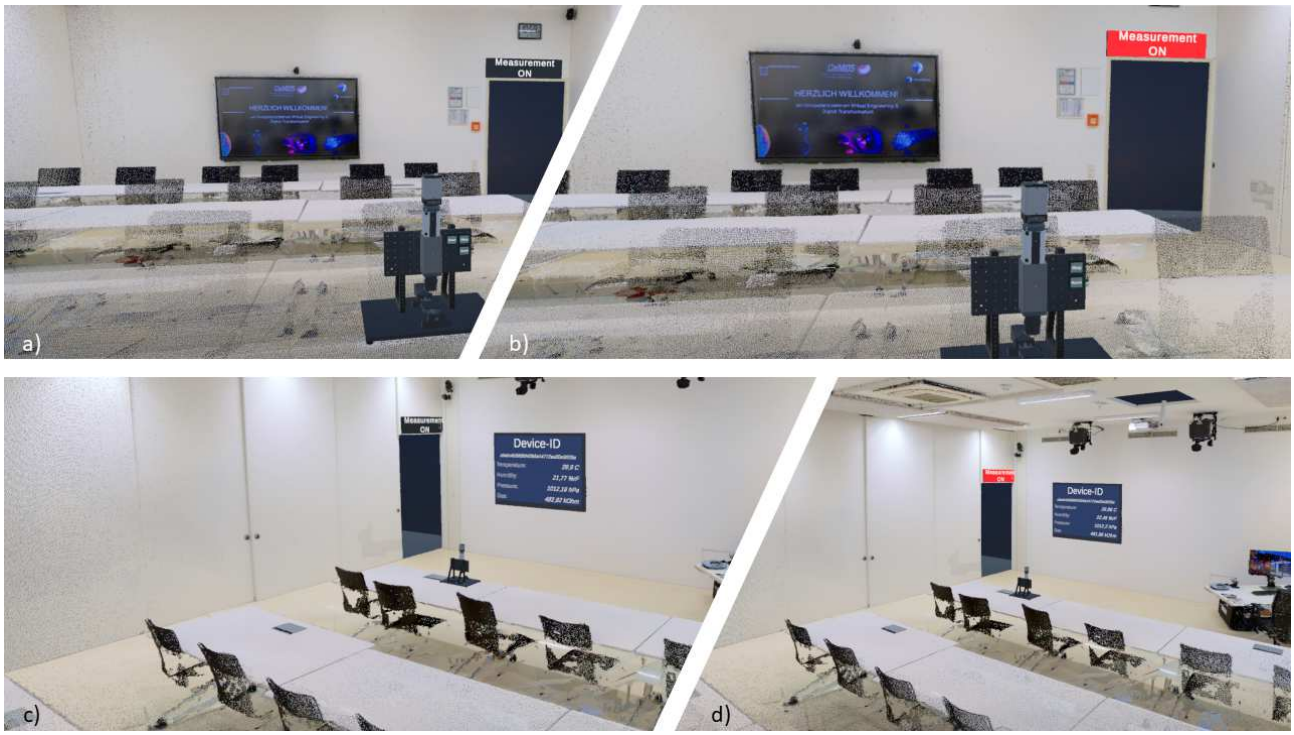

Fig. 4: Different views from the session of the Varjo XR-3. a) Shows that no one is in the room and a corresponding scan can be started b) Based on the signal, the user can recognize that someone is in the room and a measurement cannot be started. c & d) In addition to the telemetry data, it can be seen whether someone is in the laboratory (red a movement has been detected)

Using the volumetric scan as the basis for the XR application offers several advantages. First, it eliminates the time-consuming process of creating a VR environment from scratch. The scan already provides a detailed and realistic representation of the environment that can be directly imported into the application using the custom Pcx importer (https://github.com/keijiro/Pcx/) for Unity. This saves time and resources and allows to focus on developing the actual application. In addition, using a volumetric scan provides greater accuracy and immersion compared to manually created VR environments. The scan captures the environment in its actual state, including all details and features. This allows users to move and interact in the virtual or mixed environment as if they were in the real environment. However, providing surface (mesh) information is essential for real interaction, such as detecting collision or similar events. This requirement was not necessary for the built environment here, so it can be considered negligible. Another advantage of using a volumetric scan is the ability to combine the environment with other sources, such as 3D models of test setups. Additionally, sensor data or information from BIM can be integrated into the scan to create an even more comprehensive and realistic representation of the environment.

The data connection of the XR application is established via the M2MQTTforUnity Plugin. This plugin enables communication with an MQTT broker to receive and send data and control commands. The user can react to the received data depending on the situation. For example, motion sensors can signal the user whether someone is currently in the laboratory or not, which is indicated by a light signal. In parallel, the sensor values of the PT can be retrieved and visualized in real time (see Figure 4c, d). In addition, the PT can be controlled via the application. If there is no person in the laboratory, the scanning process can be started by the application. However, if someone is in the laboratory, the scan can only be started after receiving the release signal (see Figure 4a, b). Furthermore, a direct connection to RDM is integrated via a dashboard. This allows relevant measurement campaign parameters and metadata to be stored directly with the automatically generated measurement data and linked to the currently prevailing environmental parameters.

This exemplary application uses the Varjo XR-3 data glasses, which are equipped with Ultraleap Gemini (v5) hand tracking. This technology enables users to interact with the digital world in a natural way. With the help of the Ultraleap sensor, the HMD can precisely capture the movement of the hands and fingers. The application reacts accordingly to the gestures and thus enables intuitive control. By using the hands to interact with the virtual objects a similar interaction as in the physical world is given to the user. This allows for quick and easy operation of the XR application, even for new users. Direct interaction with the virtual environment through hand gestures promotes a higher level of immersion, users feel more present in the

virtual world and can concentrate better on the application. This additionally reduces accessibility barriers as no additional controllers or input devices are required. It not only saves costs but also reduces the complexity of the application and makes it more flexible and mobile. This is because users do not have to carry additional devices with them or familiarize themselves with the operation of controllers. This increases the flexibility and mobility of the XR application, as it can be used anywhere and at any time. As well as with inside-out tracking, no separate tracking area or installation of tracking systems is required. This further simplifies the use of the application. Direct interaction with the hands thus makes working in the virtual environment more efficient and productive.

7 VALIDATION AND DISCUSSION

After the implementation has been completed with the aggregation of all necessary value-adding modules, a qualitative validation and discussion can take place in regard to the related work. To this end, the four synergy fields being worked on can be analyzed here: the volumetric capturing of building data, the development of the IoT indoor measuring devices, the setup of the DT framework and the design of the XR application for displaying and interacting with all aspects of the content.

With the design of the physical IoT devices, rudimentary ambient monitoring could be realized. The results could be contextualized for the research experiments and serve to ensure the safety of the experiments. Furthermore, direct integration into the DT framework was realized with self-provisioning capabilities.

Bidirectional data and information processing was ensured regarding the architecture and interconnection of the DTs. This allows heterogeneous physical devices to be made available to the backend for example state-of-the-art IT analyses, calculations, or decision-making algorithms. The container-based structure of the UniTwin framework ensures scalability and platform independence, as well as autonomous provision of the physical devices by means of self-description methods. The APIs to the DTs opened up to the backend offer the greatest possible flexibility. However, it must be considered that as the number of DTs increases, the management effort for the entire framework and the documentation effort for interfaces and provided containers also increases.

Without existing 3D BIM building data, a state-of-the-art MLS scanner was used to generate volumetric buidling information. This allowed the differences in the results to be highlighted and compared. Using a volumetric scan also has challenges. The size and complexity of the scan data can make processing and rendering in the XR application difficult. It is therefore important to use suitable software and hardware to efficiently handle and process the data and ensure a smooth user experience. Depending on the scan, more post processing may be necessary to make the data performant on the respective devices. The calculation of meshes from the point cloud is also time-consuming. From this perspective, it can be advantageous, depending on the application scenario, to outsource the computing power to a dedicated computer and, depending on the performance, only transmit a corresponding stream to each end device. In addition, it is important to note that volumetric scans are static representations of the environment. Dynamic elements such as moving objects or people or avatars in a collaborative session require separate logic in the XR application, which still needs to be implemented. In the XR application, decisive features for the realization of the described use case could also be implemented. For example, remote maintenance and experimental scenarios are now feasible. To ensure the safety of this remote application, interlocking mechanisms were adapted through the interaction of the room sensors, the actual scanning measuring device and the XR application. Another major advantage is the interface to the RDM, whereby the measurement results can be FAIR compliant semantically enriched with metadata and context within the application.

Overall, it could be demonstrated that the integrated approach of BIM, DTs, IoT, and XR has the potential to leverage institute building management and operation of research environments synergistically. The establishment of such a joint platform makes it possible to engage in collaborative and interdisciplinary scientific discourse with the help of these technologies used. Creating an adaptive, interactive, and data-driven approach not only supports operations but also advances research and development through enhanced access to and use of data.

8 CONCLUSION AND FUTURE WORK

The synergy and combination of the technological palette of digital transformation proved to be promising for the presented work. Combining all approaches promises successful outcomes for conducting and

planning in remote and collaboration scenarios. This is especially relevant for research institutions increasingly relying on digital tools to enhance efficiency, productivity, and innovation. This overall architecture not only captures the physical layout but also incorporates digital tools and laboratory equipment used in research settings, enhancing operational efficiency. The approach also integrates RDM with these models, enabling researchers to easily access and apply relevant data for further studies. To fully exploit these technologies, a method is employed, involving point clouds recordings, IoT devices, and the creation of XR applications for interactive engagement with DTs.

The main contributions here are the generation and processing of a point cloud for the later development of an XR application in order to collect non-existing BIM data. Furthermore, the development of physical IoT room monitoring systems, which are represented within the DT framework alongside scientific measurement systems. Ultimately, an XR application combines all sub-branches into an overall solution and forms the interaction level of the entire structure with adaptive FAIR compliant RDM for research institutions. Developing a flexible, engaging, and data-centric strategy not only aids operational processes but also propels research and development forward by improving data accessibility and utilization. Overall, the entire use case emerged from the daily problems at the research institute and therefore proved to be very promising with the results available.

However, there are some limitations that need to be taken into account in the future. For example, approaches and options must be sought to ensure the execution time for clean mesh results from the creation of the point cloud. Depending on the size and use case of the XR application, the calculation via a graphics card cluster must be considered. In the future, it is planned to further investigate experiments regarding real-time recordings and processing of point cloud recordings. The framework should also be expanded to include further use cases, such as the expansion and depth of integration of research equipment, the allocation of research resources, collaboration and transdisciplinary studies and the general expansion to additional laboratory areas at the institute. The scaling and clustering of several buildings considered in this way would also be interesting to examine in the smart city context.

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🏆 *reviewed paper*

The Built Environment and Universal Design: Are Architectural Competitions a Qualified Instrument to a Better Consideration of the Diversity Dimension Impairment?

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1 ABSTRACT

Procedures of building planning and delivery are of crucial importance in generating better and more inclusive built enviroments (named “architecture” from here on) following the idea of Design for All/Universal Design. In contrast to other “products” of the everyday life, architecture is comparably complex in generation and maintenance, given the multitude of stakeholders involved in generation and operation, the longevity of interventions, the involved cost, and its role in ecological, economical and social dimension of mankind. Needless to say, architecture has a significant impact on society aspects, and thus also on the different diversity dimensions of societies. To ensure high quality in interventions toward the built enviroment, the instrument “architectural competitions” has been established decades, if not centuries ago. Today, usual architectural competitions target the call for high-quality design ideas or suggestions for specific requirements within the built enviroment. Architectural competitions differ in their scope, their procedural and organisational structure, the number of competition entries, and other methodological aspects. Typical timeframes for architectural competitions take 6 to 8 weeks of preperation work and 8 to 15 weeks of time for competition entry developments, and – in most cases – the winning project is intented to be realized/built. This paper presents concept, method, and results of an empirical study pertaining to the relation of architectural competitions and the consideration of Universal Design/Design for All aspects within the competition. Thereby, both the call for entries and the overall provided information, as well as a comparable large number of competition entries was examined in a structured process: In a first step, we generated a checklist template that targeted different aspects related to Universal Design/Design for All in the framework of the competition call for tender. The checklist was also adapted for evaluation of aspects of Design for All within examined competition entries. In a second step, recently conducted architectural competitions were selected. For these competitions we collected both the call for tender documents, as well as selected competition entries. Subsequently, the checklist was applied on the collected data, to generate both quantitative results and to identify good and bad practices regarding the consideration of universal design aspects within the competitions.

15 different architectural competitions and 76 competition entries were analyzed. The consideration of Universal Design aspects in the entries happened mostly rudimentary, but some specific best practice and worst practice cases could be identified. A major finding of the overall evaluation procedure is that – disappointingly – there is a lot of improvement potential for a better consideration of Design for All/Universal Design aspects in this early phase of building delivery processes.

Keywords: Empirical Study, Diversity Dimensions, Impairment, Design for All, Architectural Competitions

2 DEUTSCHE KURZFASSUNG

Zweifelsfrei sind die Verfahren, die in Bauplanung und Bauumsetzung angewandt werden, von entscheidender Bedeutung für das Erstellen hoch- und höchstqualitativer gebauter Umgebungen (in diesem Beitrag soll dafür – recht ungenau – der Begriff „Architektur“ verwendet werden), die auch den Ideen und Grundsätzen von Design for All bzw. Universal Design folgen. Im Gegensatz zu anderen „Produkten“ des täglichen Lebens ist Architektur in ihrer Entstehung und Instandhaltung vergleichsweise komplex, wenn man die Vielzahl der an der Entstehung und dem Betrieb beteiligten Akteure, die Langlebigkeit der

Interventionen, die damit verbundenen Kosten und ihre Rolle in der ökologischen, wirtschaftlichen und sozialen Dimension der Menschheit bedenkt. Architektur hat einen sehr großen Einfluss auf verschiedenste Aspekte der Gesellschaft, als solche auch auf die Diversitätsdimensionen, die in einer Gesellschaft bestehen. Als ein Mittel zur Sicherstellung hochqualitativer Veränderungen der gebauten Umwelt (sei es „Neubau“ oder „Umbau“/Sanierung) hat sich der Architekturwettbewerb als Instrument über Jahrzehnte, wenn nicht über Jahrhunderte, etabliert. Die heute üblichen Architekturwettbewerbe zielen in ihren Ausschreibungen und Durchführungsverordnungen auf qualitativ hochwertige Entwurfsideen oder Vorschläge für spezifische Anforderungen der gebauten Umwelt ab. Architekturwettbewerbe unterscheiden sich durch ihren Umfang, ihre Verfahrens- und Organisationsstruktur, die Anzahl der Wettbewerbsbeiträge und andere methodische Aspekte. Typische Zeiträume für Architekturwettbewerbe betragen 6 bis 8 Wochen Vorbereitungszeit und 8 bis 15 Wochen Zeit für die Entwicklung und Abgabe des Wettbewerbsbeitrags. In den meisten Fällen wird das Siegerprojekt realisiert oder dient zumindest als Richtschnur für folgende Verfahrungsschritte wie Verhandlungsverfahren. In diesem Beitrag werden Konzept, Methode und Ergebnisse einer empirischen Studie zum Verhältnis von Architekturwettbewerben und der Berücksichtigung von Universal-Design-/Design-for-All-Aspekten im Wettbewerb vorgestellt. Dazu wurden sowohl Auslobungsunterlagen wie auch die insgesamt im Rahmen von Wettbewerben untersuchten Dokumente, die den Teilnehmerinnen und Teilnehmer zur Verfügung gestellt werden wie auch eine große Anzahl an Wettbewerbsbeiträgen in einem strukturierten Prozess untersucht: In einem ersten Schritt wurde eine generische Checkliste erstellt, die sich auf verschiedene Aspekte in Zusammenhang mit Universal Design/Design for All bezog. Diese Checkliste wurde in Hinblick auf eine strukturierte Bewertung sowohl von Wettbewerbsauslobung und Wettbewerbsdokumenten einerseits und auf Wettbewerbsbeiträge/ Einreichungen andererseits erstellt. In einem Folgeschritt wurde eine Auswahl an jüngst abgehaltenen Wettbewerbsverfahren ausgewählt. Für diese Wettbewerbe wurden die entsprechenden Unterlagen (Ausschreibungsunterlagen, Wettbewerbsbeiträge) gesammelt und die zuvor erstellte Checkliste darauf angewandt. Hierbei wurden sowohl quantitative Aspekte erfasst, wie auch qualitative Aspekte berücksichtigt, letztere vor allem um „Good“- and „Bad Practise“-Beispiele/Praktiken hinsichtlich der Berücksichtigung von Aspekten des Universal Designs in den Wettbewerben zu identifizieren.

Es wurden 15 verschiedene Architekturwettbewerbe und 76 Wettbewerbsbeiträge analysiert.Die Berücksichtigung von Universal-Design-Aspekten in den Beiträgen erfolgte meist lediglich rudimentär, es konnten jedoch einige spezifische Best- und Worst-Practise-Fälle identifiziert werden. Ein wesentliches, wenngleich enttäuschendes Ergebnis des gesamten Bewertungsverfahrens/dieser Studie ist, dass es viel Verbesserungspotenzial für eine bessere Berücksichtigung von Design-für Alle-/Universal-Design-Aspekten in dieser frühen Phase des Planungslebenszyklus gibt.

3 INTRODUCTION

In the context of diversity management and diversity of people, the built environment plays a special role: Almost all people spend a large part of their lives in a built reality designed by (other) people, be it for living, working, spirituality, leisure, sport or many other activities. As such, it can be said that "architecture", if one wishes to use this umbrella term for the design of the built environment, concerns all people. As such, the consideration of diversity or an inclusive approach in any design or construction intervention or further development is a necessity and should be considered a non-negotiable principle. While in all four layers of diversity, as suggested by Gardenswartz and Rowe in 2003 (Gardenswartz and Rowe, 2003), architecture and the built environment plays different important roles, e.g. as an interface, spaces for spirituality, etc., the built environment in its physical/material appearance is immanent for some of the inner dimensions (age, gender, sexual orientation, impairments, social origin, and ethnicity). Indeed, the dimensions of age and impairments directly require adaequat built environments to be inclusivly usable, which is widely known to be adressed in the domain of Design for All. Designing and realizing/changing the built environment is a complex process involving many stakeholders who naturally have not the same or rather different interests, which may even be diametrically opposed (think of costs versus amenities, or competition for space between people who want to get somewhere quickly by car versus people who want to live centrally in a quiet, leafy urban location). Typically, this process takes place at different scales, which must be well coordinated in order to achieve design objectives and which – adding a lot of complexity - must react to each other in mostly iterative and interdependent processes. Interventions in the built environment are usually of a long-lasting

nature (i.e. the lifespan of buildings and infrastructures is quite long compared to a human lifespan) and are considered cost-intensive, both in terms of construction as well as maintenance and upkeep. Especially in Central Europe, or in the German-speaking area, the construction industry is also considered to be highly regulated, euphemistically Germany and Austria (and to a lesser extent Switzerland) are referred to as world standards champions. In order to achieve the best possible architecture and infrastructure that is both useful, attractive and economically viable, the "competition" method has been developed. In the subsequent sections, we discuss some aspects of architectural competitions and Universal Design for the built environment.

3.1 Some aspects of architectural competitions

The Chamber of Civil Engineers for Vienna, Lower Austria and Burgenland, Section Architects, provides a comprehensive overview of the background, structure and aim of architectural competitions in Austria (Zt-Kammer 2019). According to this document, an architectural competition is an integral part of the implementation of an architectural project as well as for the tendering process. The lead time for the preparation of such a competition usually extends over a period of 6 to 8 weeks. During this period, the tender documents are drawn up, judges, consultants and preliminary examiners are identified and acquired, and organizational measures are taken. The actual competition regularly takes place over a period of 8 to 15 weeks and includes steps such as the announcement, the processing of the task by the participants, the preliminary examination and the final evaluation. Once a competition has been completed, post-competition steps such as negotiations between the winning participants or the transfer to the realization phase with the winning participant is started. According to the chamber publication, the aim of holding architectural competitions is to generate comparable solutions for a specific project within a short period of time. This process ensures the targeted feasibility of a design, promotes transparency in the decision-making process, supports a high level of innovation and offers a high degree of legal certainty for both participants and tenderers. There are three basic forms of architectural competitions: the open competition, the restricted competition and the invited competition. Public tenderers (in the EU member states) must observe the EU thresholds in accordance with BVergG 2018. The open competition is the standard procedure (which also is the most wished for form by chamber officials) and is suitable for projects of different sizes as it allows an unlimited number of participants. This open format promotes inclusive participation and enables architects to be fully represented, regardless of the size of the project or the number of stakeholders involved. In constrast, restricted architectural competitions are characterized by an exceptional procedure and are intended for particularly demanding tasks. An unlimited number of interested parties are invited to express their willingness to participate. This is followed by a selection process in which certain participants are invited to submit a competition entry. This selective approach enables a targeted approach and participation of professionals in situations that require specific skills. Invited architectural competitions, the third basic type, are used in particular for smaller, very specific tasks and are also characterized by an exceptional procedure. Here, a limited number of participants are specifically invited to submit a design proposal. This selective participation practice enables efficient and focused participation, especially in situations where the task requires a limited number of specialized professionals. Project development, which regularly serves as the basis and prerequisite for the tender, is completed before each competition procedure. In this phase, preliminary technical investigations, user surveys, feasibility studies and clarifications with the authorities are carried out. Architectural competitions in Austria are subject to the Federal Procurement Act BVergG 2018 as amended and the Architecture Competition Rules WOA 2010, which consist of three parts and were formulated by the Chamber of Civil Engineers (Zt-Kammer 2019). If one follows the explanations of the Zt:Kammer (Zt-Kammer 2019), it can be summarized that architectural competitions are an essential procedure for the realization of innovative projects.

3.2 Some general thoughts on Design for All in the built environment

Everding et al. (2015) state that it can be observed that increasingly more cities and community increase their living standards by consequently implementing design-for-all principles. Whereas this sentence draws a positive picture of improved built inclusion, it also underlines the causal connection between living standard quality and inclusive built environments. Obviously, the more people can life their live free of obstructions in a self-determined way, the more liveable cities and villages are perceived. Grundner (2023) emphasizes that a transition from Integration (adapting of people to fixed environmental settings) to Inclusion (adapting

environmental settings to the individuality of people) is a core concept of Design for All, as well as understanding individuality as a society asset. Grundner underlines that this transition not yet has been conducted. Legal requirements toward Universal Design should be understood as what they are: The lowest but immanent to be fulfilled requirement step. Aspects of building and urban planning that lead to more inclusive spaces include – amongst others - technologies utilizing the 2-senses-principle for informative and orientative systems, tactile guidance systems for the blind, consideration of dimensions of different elements in the built environments (elevator floor space, door widths, …), and many more. In part, these measures are demanded by legal documents, in part these measures are beyond the minimum requirements, but can be causal for a better inclusive experience for large numbers of people. A wide variety of international and national legal documents stipulate the inclusiveness of the built environment. Thereby, not only specific laws and standards (e.g. ÖNORM B1600, 2023, OIB RL4, 2023)addressing the built environment encompass important aspects, but also more general laws, e.g. laws toward public procurement (BVergG 2018)

3.3 Design for All in architectural competitions?

Given the meaningfulness of both Design for All aspects and architectural competition procedures in the early stages of the building planning and delivery processes, one would assume that there are some guidelines how to consider Design for All in Architectural Competitions. The nationwide chamber of architects in Austria did publish back in 2010 (with a novel edition of 2022) a guideline that encompassed holistic recommendations for conducting architectural competitions (WOA 2010). Thereby, Design for All is mentioned once in form of the german term “Barrierefreiheit”, along other dimensions of diversity in the preamble (English translation conducted with DeepL):

Architektinnen und Architekten haben die Aufgabe, bei ihren Arbeiten alle Menschen in ihrer Unterschiedlichkeit und Vielfalt zu berücksichtigen. In der Planung ist auch den gesellschaftspolitischen Ansprüchen der Gleichstellung, Gleichbehandlung und Barrierefreiheit für alle Menschen unabhängig von Geschlecht, Alter, Religion, Ethnie, intellektuellen Fähigkeiten, gesundheitlichen Einschränkungen usw. zu entsprechen. Um die Präsenz von Frauen in technischen Berufen zu erhöhen, sollten insbesondere Gleichbehandlung und Teilhabe von Frauen in Planungsprozessen gestärkt werden. Der Architekturwettbewerb, der Gestaltung und Ästhetik, Ökologie und Ökonomie, soziale Nachhaltigkeit und Partizipation in die Entscheidungsprozesse zur Qualität unserer gebauten Umwelt einschließt, ist ein wesentliches Instrument zur Umsetzung dieser Ziele. Der offene Architekturwettbewerb liefert eine Vielfalt unterschiedlicher Entwurfskonzepte für die Planungsaufgabe. Er zeigt die gesamte Bandbreite möglicher Lösungen für die Aufgabenstellung und schöpft damit das Potenzial, das der Wettbewerb für die Entscheidung von Gestaltungsfragen bietet, maximal aus. Er richtet sich an eine unbeschränkte Anzahl von Teilnahmeberechtigten, die mit der Veröffentlichung des Wettbewerbs zur Abgabe von Wettbewerbsarbeiten eingeladen werden. Die Offenheit im Sinne einer niederschwelligen Teilnahmemöglichkeit für Architekturschaffende ist entscheidend für die Qualität des Wettbewerbsergebnisses und mit entsprechenden Rahmenbedingungen zu fördern.	Architects have the task of considering all people in their diversity and variety in their work. In planning, the socio-political demands of equality, equal treatment and accessibility for all people regardless of gender, age, religion, ethnicity, intellectual abilities, health restrictions, etc. must also be met. In order to increase the presence of women in technical professions, the equal treatment and participation of women in planning processes in particular should be strengthened. The architectural competition, which includes design and aesthetics, ecology and economy, social sustainability and participation in the decision-making processes on the quality of our built environment, is an essential instrument for achieving these goals. The open architecture competition provides a variety of different design concepts for the planning task. It shows the entire range of possible solutions for the task and thus maximizes the potential that the competition offers for deciding on design issues. It is aimed at an unlimited number of eligible participants, who are invited to submit entries when the competition is published. Openness in the sense of a low-threshold participation opportunity for architects is decisive for the quality of the competition and must be promoted with appropriate framework conditions

Diversity is mentioned as a term on other positions in the document, namely in the assembly of juries for competitions and external consultants, which should be chosen under consideration of aspects of diversity. Moreover, the documents suggest “diversity of planning concepts” and “diversity amongst participating planners” as major pillars of architectural competitions. The diversity of the the users of architectural competitions (future dwellers, occupants, neighbours, the general public) is only addressed in the preamble, quoted above.

3.4 Research objective, research question, hypotheses

Given the settings described in the subsections above, the major question arises, if architectural competitions today can be considered as a well-suited instrument for ensuring the consideration of the diversity dimension “impairment” or not. In other words, if the “Design for All”-Approach that generally addresses this dimension is a criterion in architectural competitions. Based on the prevalent knowledge of the authors, who majorly have been working in architectural offices and have been involved in competition works, the following hypotheses have been formulated: (i) A minimal consideration of the diversity dimension impairment in tender documents is stipulated by law, and thus can be found in the documents ex lege. A consideration surpassing these legal minima is strongly dependent on the tendering organization (in tender

documents) and the architects entering competition entries (in the project entries), but shall not be assumed as a given feature in these documents. (ii) Per se, terms such as "barrier-free" are considered as important by all stakeholders involved, but it seems that these are majorly utilized as cursory buzzwords, rather than in-depth considered. As a summarizing research question of this contribution, one could reckon the following questions: What can be found in typical case study architectural competition documents about the diversity dimension impairment and its addressing via "Design for All"? To which extent can be said that architectural competitions consider diversity and design for all?

4 METHODOLOGY

To adress the named research questions, we deployed the following step-by-step methodology:

4.1 Development of a Checklist

A checklist for a structured, qualitative evaluation of different diversity dimension was considered as a good instrument. While a clear focus was set on the diversity dimension impairment, some other aspects of other dimensions were considered as equally important and thus foreseen for integration. Moreover, as format of the checklist a spreadsheet format was favoured, and both tender documents and competition entries should be evaluated in different sections of the same spreadsheet.

4.2 Search and Selection of architectural competitions and their documents/documentations

The authors utilised different web-ressources and available information coming from their employing architectural offices to identify and select competitons suitable for evaluation. Criteria for using the architectural competitions were as follows: (i) a sufficient documentation of the competition documents and entries is available; (ii) the competition as such is a finished and concluded process; (iii) the considered competitions should encompass different clients and different design tasks; (iv) the considered competitions should encompass different scales/extents and different levels of realization/stages of realization (idea competitions, competitons addressing a realization, etc.); (v) the considered competitions should encompass national (Austrian) and international competitions.

4.3 Application of the checklist on the selected competitions

The selected architectural competitions (encompassing both tender documents and competition entries) were subjected to the checklist-based quantitative and qualitative evaluation.

4.4 Analysis of the checklist results

Based on the filled checklists and the source documents of the competitions, a comprehensive analysis was conducted. Thereby, a comparison based both on quantitative and qualitative aspected was done, as well as the identification of good and bad practice aspects of the pertinent competitions.

4.5 Non goals and accepted limitations of the methodology

Given that a certain part of the study has a quantitative character, it seems important to underline that the goal of the study never was to analyze a very large number or even "all" competitions within a certain temporal and spatial extent. Rather, the limited number of competitions and competitions entries was selected as described above and an empirical evaluation approach on this case studies was deployed. This was done to identify trends, and to discuss and illustrate specific aspects of the examined competitions, rather than to address something such a "countable objectivitiy" (which – as long as evaluation is done on qualitative aspects by human beings anyhow impossible to reach). Toward this end it needs to be stated that the pertinent work in this study was limited in available time and effort, and had to focus on a specific exemplaric number of competition contributions.

5 RESULTS AND DISCUSSION

In the following section, we structure the achieved results into different parts, encompassing the developed checklist, a comparative overview about the selected and analyzed competitions, the aggregated results of the analysis of the competitions and checklists, as well as good and bad practice observations identified in specific contributions.

Name of the competiton	**Year|Location| Gross Area|cost frame**	**Type of Building**	**Typ of Competition**	**Prize money (agg.)**	**Eval. Comp. entries**
Former Swimming Pool Hall, Klagenfurt	2023|Klagenfurt(AT)| GA:17.325m²|n.a.	Multipurpose (Education, Commerce, Services) & residential (150 residential units)	invited, single-stage realization competition	135.000€	9
Square Design Domplatz . Innsbruck	2023|Innsbruck(AT)| GA:3.800m²|3 Mio €	Place in front of Innsbruck Dome including Church entry	open, single-stage realization competition in the sub-threshold area	47.100€	6
Education Center Brückl	2023|Brückl(AT)| GA:1.760m²|10,5 Mio €	Retrofit and Extension, New Gymnasium Hall, barrierfree connection between old and new part	EU-wide, open, single-stage realization competition in the upper threshold range	64.500€	7
Neues Landgut – Baufeld 11	2022|Wien(AT)| GA:14.800m²|n.A.	Residential Building	open, single-stage realization competition in the upper threshold range	120.000€	3
Retrofit/in-Part new erection of School in 10th Vienna district.	2023|Wien(AT)| GA:6.345m²|7,6 Mio €	Secondary School with 32 classes	EU-wide open, single-stage, anonymous realization competition	134.000€	3
New Building of a School	2023|Baden(AT)| GA:n.a.|26,5 Mio €	Secondary School with 32 classes	EU-wide open, single-stage realization competition	111.000€	3
Areal Hotel InterContinentalVienna	2013|Wien (AT)| GA:max.62.500m²| n.a.	Conf. Center Hotel, Sport & Spa	Non-open, two-stage realization competition, upper thresh. range	324.000€	3
Klinik Hietzing Gesamtentwicklung	2023|Wien (AT)| GA:n.A.|n.A.	Hospital	open, two-stage realization competition(upper thresh. range)	500.000€	3
Kranebitter Allee 16, Innsbruck	2021|Innsbruck(AT)| GA:1.770m²| n.A.	(New) residential Building	invited, single-stage realization competition	52.000€	3
Neubau Bildungseinrichtung	2021|Wien(AT)| GA:n.A.|n.A.	Bildungscampus	open, single-stage, anonymous realization competition	142.000€	5
Kinderhaus Bürs	2023|Bürs(AT)| GA:1.300m²|5,9 Mio €	Leisure (multifunctional for children and adults, education)	open, single-stage, anonymous realization competition	51.000€	3
Neubau Police Detention Center, Klagenfurt	2023|Klagenfurt(AT)| GA:3.000m²|5,9 Mio €	Temporary Detention Center	open, single-stage, anonymous realization competition	77.000€	1
Rehab.C. for Terrorism Victims/ Iraq	2022|Firdos Par (IRQ)| GA:n.A | n.A.	Rehabilitation Centre	International annual open ideas competition	10.000$	10
Daycare centre for autistic children	2022|NewHaven (USA)| GA:n.A.|n.A	Daycare Center for autistic children	Open idea competition, architectural design competition	6.000$	4
Zero Threshold	2019|OldBrooklyn (USA)|GA:n.A.|n.A.	Residential Building & Square Design	Open idea competition	9.000$	4

Table 1: Overview about the evaluated competitions.

5.1 Finalized Checklist

The spreadsheet-based checklist was designed to encompass two sections for each competition. The first "general" section adresses general information of the competition and the tender documents. Important means of data in this part include an identification name of the competition, key information about the competition (name and type of the competition, form of conduction, objective of the competition, target

audience of the to be-developed architecture, year and duration of the competion, location and adress, size of the site, envisioned floor areas and room programmes, type and name of the client), followed by specific information on the diversity dimension impairment if available in the tender documents. Moreover, the composition of the jury (gender, domain expertise and background), prize money and distribution of prize money, number of participants in the competition, and – as an evalution – if aspects of Design for All are sufficiently considered in the tendering documents, or if there is potential for improvement. In the "specific" section, analyzed competition entries are repetively evaluated by the following structure: Achieved rank of the competition entry, authors (including team composition and consultants), Consideration of Design for All aspects in the competition entry, adressed other diversity dimensions, jury comments on aspects of Design for All in the specific entry (if available), plus a subjective evaluation by the authors of this contribution if and to which extent the competition entry sufficiently, good, excellent or insufficiently considered aspects of Design for All. Moreover, in case any problematic suggestions interdicting an inclusive environment were identified, these also were commented on in the checklist.

5.2 Selected and analyzed competitions

All together 15 competitons were considered in this study, and 76 competition entries were evaluated. The sources of the data were in part the still existing web repositories of the competition tender documents and websites denoting the outcomes. Moreover, the business networks of the authors of this contribution were used to acquire missing data. Table 1 illustrates the evaluated architectural competitions, Table 2 comments on the consideration of Design for All and the diversity dimension impairment in the tender documents and the evaluated competition entries.

It can be seen in the tables that the consideration of aspects of Design for All varies amongst the different competitions.

5.3 Aggregated results from analysis

The following general observations could be derived from the checklist-bases analysis:

- In the international competitions, the number of linked or cited guidelines and directives was marginally small in comparison to competitions advertised in Austria (where these were cited as essential literature), nevertheless a very strong interest in diversity and consideration of aspects of universal design could be found in many contributions from architects, which in some cases represented a core element of the respective contribution. This may also have something to do with the objectives of these competitions, some of which are very social in nature.
- In some of the competitions, quite specific requirements for accessibility were even mentioned in the title of the competition (e.g. "barrier-free connection between old and new building"), but it was left to the planners to decide how to achieve this in addition to the usual guidelines and standards. However, no consideration was given to this in the jury-evaluation of these competitions.
- In other competitions, e.g. the Police Detention Center in Klagenfurt, part of the "creative performance" was taken away from the competition participants by including specifications for interior design (see Best/Worst Practice below) in the invitation to tender.
- The competitions examined were all of a comparatively recent nature (most of them within the last few years) and are therefore all subject to the same level of knowledge and standardization with regard to accessibility and diversity dimensions. The competitions differed significantly in terms of the area program (size and content), but also in terms of the monetary order volume and the prize money. Nevertheless, no causal or correlative link between the amount of prize money or the monetary volume of the respective competition and increased or more stringent accessibility requirements can be established on the basis of the competitions examined.
- It is noteworthy that among the 15 competitions, there were specific building uses that required consideration of the diversity dimension impairment (DDI), particularly in terms of building use (e.g. hospital, rehabilitation center, public squares), but here too, no mention/reference was made in the competition brief that went beyond the other competitions. On the one hand, this speaks for the high standard in the standards and guidelines, especially in Austria, but on the other hand, it suggests that the DDI is only one of a large number of requirements for the buildings, which is not overly

emphasized. It might also be possible to detect a certain "technocratic" attitude towards the content of the competition itself (e.g. hospital), while there is no need to consider DDI aspects beyond the minimum.

Name of the competiton	**Comment on diversity dimension impairment in tender documents ("requirements")**	**Comment on diversity dimension impairment in competition entries**
Former Swimming Pool Hall, Klagenfurt	Escalator/Lift for the Supermarket, minimum floor areas for barriere-free toilets in the center for kids.	+: outdoor surfaces optimized for easy accessibility. -: long and contorted access corridors; Relax areas unreachable for wheelchair users.
Square Design Domplatz . Innsbruck	Accessibility of both square and the church needs to be guaranteed, as well as for the adjacent Herrengasse; tactile orientations system is required.	+: Ramps to church portal; Accessibility routes majorly short -: lack of handrails and tactile orientation systems for the blind, despite explicit requirement in the tender documents
Education Center Brückl	All Entrances need to be free of barriers; Additional specifics for different parts of the complex.	+: Kiss & Ride – Zone of limited size ensures walking paths for children; All projects completely free of barriers in the principle outline. -: Only one project encompasses parking lots for people with disabilities; difficult, contorted Geometry of existing structures hampers orientation.
Neues Landgut – Baufeld 11	Parking lots for people with disabilities demanded in the garage.	+: one nivellement of street level; barrierfree storage rooms. -: in general lack of integration of design for all parameters amongst all projects.
Retrofit/in-Part new erection of School in 10th Vienna district.	Old and New Part need to be connected one one nivellement, main entrance to be free of barriers, outdoor and indoor infrastructure need to be free of barriers everywhere.	General observation: Minimum requirements are fulfilled, but amongst the evaluated projects specific aspects of Design for All can not be found.
New Building of a School	n.A.	Focus on barrierfree entrances and toilets; Minimum requirements have been widely fulfilled.
Areal Hotel InterContinental Vienna	n.A.	Design for All Aspects: little niveausteps, barrierfree access/entrances, sufficient number of elevators. Challenges connected to the interior staircases, as well as the Design-for-All-Performance of the main entrance.
Klinik Hietzing Gesamtentwicklung	n.A.	-: While the project addresses different occupant groups, all measures toward Design-for-All are just integrated on a superficial level.
Kranebitter Allee 16, Innsbruck	All floors need to be accessible without barriers. Privacy of the flats as well as being free of barriers in all residential units is required.	+: Elevators, barrierfree access; Challenges: Small Sanitary-rooms; usability for young persons and children
Neubau Bildungseinrichtung	n.A.	-: Parking lots rather far away from the building; Entrance for employees is suboptimal.
Kinderhaus Bürs	Minimum requirements names, other than that, just keywords.	The little complexity of the building contercarates some suggested Design-for-All solutions.
Neubau Police Detention Center, Klagenfurt	Design for All is named only indirectly in textual descriptions, but the tender documents include schematic room setups that strongly include design for all Aspects.	Some competitions entries strongly rely only on the schematics of the tender documents (used as placeholders).
Rehab.C. for Terrorism Victims/ Iraq	Requirements for future occupants described in detail	Clever solutions for offering one-level accessibility.
Daycare centre for autistic children	Requirements just described in keywords.	Projects utilize materials and topology for future occupants.
Zero Threshold	Requirements are described generally in text form (to allow different approaches)	Design for All is considered as design element by many projects. In one project a "garden of ramps" is integrated as central element.

Table 2: Aspects of Design for All in tender documents and different competition entries of the examined competitions.

- In the jury statements that were also studied, accessibility was used as an "argument" on one or two occasions, but to a negligible extent compared to the number of competition entries. Furthermore, in

most cases it was not directly argued whether something was accessible or not, but merely that an accessible solution could potentially be better relocated to another place of execution/design. In most jury statements, however, accessibility was not even mentioned as a term or justification.

- With regard to the composition of the juries, it can be noted that they were predominantly male-dominated. If only the judges and substitute judges whose professional background was "architecture" are taken into account, the ratios are slightly better balanced, but still heavily male-dominated. Dedicated judges or consultants who would have assessed accessibility could not be identified in the jury compositions.
- Based on the competition entries submitted and analyzed, it can be stated that the consideration of aspects of DDI and accessibility is usually always the responsibility of the architectural designers and is almost never carried out externally by consultants (who usually cover technical or landscape design aspects).
- When analyzing the competition entries, the impression predominantly arose that the entries or their authors had made an effort to meet the necessary minimum in terms of accessibility (so that the competition entry would not have been rated lower as "not barrier-free"), but in almost all cases the textual and in some cases graphic application of the usual minimum requirements remained. It was very often noticeable that "barrier-free" was used as an adjective or attribute for other information (e.g. barrier-free access, barrier-free lift) and was not the subject of the design itself. In other words, it was often used "brick-like" as an attribute (comparable to the "yellow Lego brick"), but no "innovation" or particularly "creative" approach to DDI was proposed. The question arises as to whether the effort of a "special" consideration, the special design – going beyond the minimum standard specifications – can or should be expected of competition participants at all, if one thinks of open competitions, where sometimes a large number of participants take part and the chances of success are comparatively low. Of course, this idea also means that if "better consideration" is given in the requirements documents, better consideration could also be given in the competition entries.
- Fundamentally, it is very difficult to compare competition entries due to the complexity of building and plaza design. However, this of course does not only apply to the aspects of accessibility: as early as 2012 and 2017, Pont et al. (2012) and Pont and Mahdavi (2017) noted that "numerically" determinable performance data of competition entries and "rankings" do not necessarily correspond directly, even if experts would rank these competitions differently. The aforementioned publications used aspects of sustainability and energy performance. It seems quite clear that this is no different with the diverse and complex integration of the DDB. Ultimately, the question also arises as to whether and how people who do not have an internal view of a diversity dimension (and most architecture professionals are probably not equipped with an internal view of "disability") can achieve sufficient consideration of this. This last point in particular shows why "self-awareness" can be an important aid.

5.4 Best and Worst Practice of the analyzed case study competitions

5.4.1 Worst Practice 1 – Platzgestaltung Domplatz Innsbruck

In this competition, the tender documents demanded a tactile orientation system and barrierfree access. Moreover, a detailed plan illustration including the tactile orientation system in scale 1:50 or 1:20 was demanded by the tender documents. All together, 36 competition entries were delivered. Thereby, only two entries illustrated the tactile orientation system, although that was demanded (less than 5%). These two entries were amongst the 6 awarded projects, and included the winner project and a runner-up project (rank 4-6). Projects without a detailed plan view were not amongst the awarded ones. Figure 1 illustrates the winning projects' detail plan view (top) and one of the ranked projects, which does not really consider any aspects of Design for All within its plan.

Furthermore, the jury protocols just focus on the general morphology of the corresponding design suggestion and do neither in general nor in detail state anything about Design for All.

5.4.2 Worst Practice 2 – Neubau Bildungsreinrichtung Hinaysgasse

In this competition, one of the awarded projects (3rd rank) showed serious flaws in the consideration of Design for All aspects. Parking lots for persons with mobility impairments had been situated on the opposite site of the main entrance, so that people with mobility impariments had a considerably longer way from parking lot to the entrance than all others, and were forced to use public street sidewalks in order to reach the main entrance. Moreover, such positioning of relevant infrastructure for the disabled could cause serious issues pertaining to orientation. While the jury again did not mention any aspects of Design-for-All consideration in the protocol, one could get the impression as the planners tried to hide away "unwanted" parking lots for disabled in their concept. Generally speaking, it can be observed in many architectural designs that the additional waylength for people with disabilities is not sufficiently considered.

5.4.3 Best Practice 1 – Polizeianhaltezentrum Klagenfurt

This competition needs to be mentioned as a best practice project for its excellent tender document descriptions and pre-definitions of spaces: Here, schematic plans of arrest cells were provided and additionally the tender document demanded of the planners that multi-person arrest rooms should allow a modular transformation to a 1 person barrierefree detention space. Moreover, for specific spaces and details of the to be designed building, clear requirements, such as barrierfree furniture, a rich-in-contrast orientation system, and a barrierfree courtyard design, were defined as mandatory. Figure 2 illustrates the two person detention rool schematics as provided in the tender document.

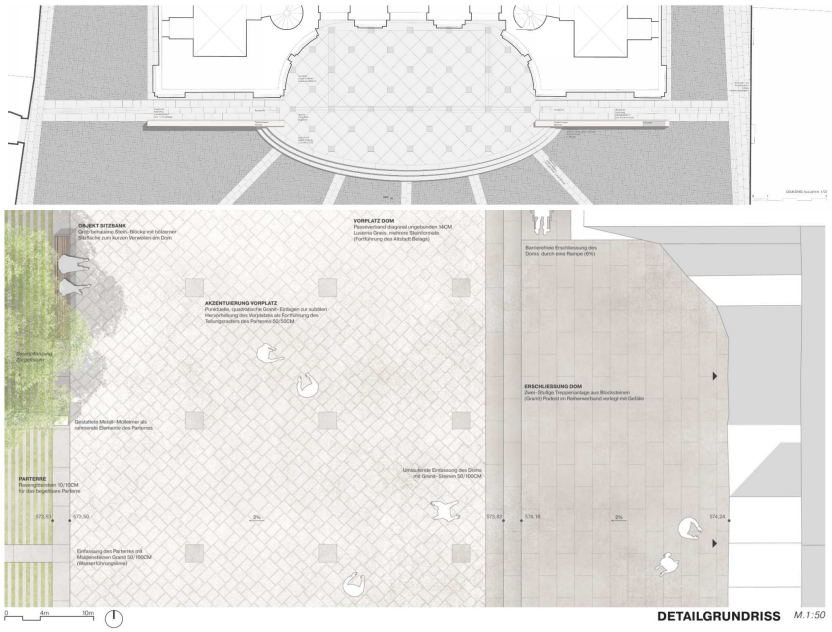

Fig. 1: Top: winning project of the Domplatz competition encompassing a tactile orientation system; bottom: awarded project of the Domplatz competition widely ignoring any general accessibility aspects.

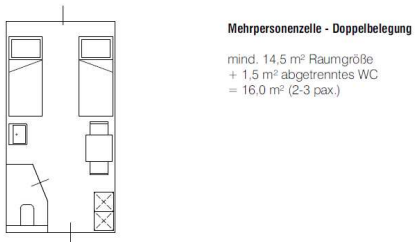

Fig. 2: Suggested detention room schematics as provided in the tender documents of the Detention Center Klagenfurt competition.

5.4.4 Best Practice 2 – Retrofit and NewBuilding in Vienna, 10th district

This competition has to be mentioned as inclusion was a big topic in the tender documents which was emphasized troughout general description and detailed requirements. Detailed descriptions of what is awaited by the planners regarding consideration of inclusion are provided and by far surpass the minimum requirements.

6 CONCLUSION

Participation in international architectural competitions, which are freed from strict specifications, opens up a rich playground for creative development. However, this freedom brings its own challenges, particularly with regard to the comprehensive consideration of accessibility - a challenge that exists at various levels of planning and execution. In the specific "competitions" stage of the process, there is a clear reduction of accessibility to mobility impairments, with the focus primarily on people with wheelchair dependency. However, this limited perspective neglects a number of other, equally important aspects such as visual accessibility, people with mental impairments, guidance systems and multi-sensory principles. The balance between the freedom of specifications and the necessary consideration of different dimensions of accessibility becomes a central dilemma. A striking disparity also emerges in the discourse on accessibility. While the term is used in (many) written contributions, this is often not reflected in graphic representations or even the opposite (representations of structural conditions that are decidedly not barrier-free). The boldness with which accessibility is implemented in certain areas such as entrances and sanitary facilities is at odds with a consistent concept that often takes little account of accessibility and should fundamentally consider the needs of permanently affected user groups, especially in educational facilities such as schools or building uses whose purpose is to care for or look after people. The analysis of jury statements reveals a further challenge. These are often focused on specific architectural aspects and only superficially or not at all address the various dimensions of diversity, in particular the dimension of "disability". This deficit continues in numerous international tenders and planning processes, in which accessibility is often reduced to merely meeting minimum standards, such as the minimum number of accessible parking spaces. The route from parking spaces to the main entrance becomes a metaphorical mirror image for the limited perception of accessibility, which focuses on structural access. In reality, however, accessibility extends beyond the physical dimension and includes visual guidance systems, acoustic signals and places of rest. However, the pragmatic usability of these elements often remains unclear, reinforcing the superficial focus on accessibility as a buzzword. In Austria, the situation with regard to standards and guidelines may be comparatively favourable, but internationally there is often a "freestyle" approach, which poses a challenge for the global standardization of accessibility. The focus here should not only be on scale, but also on a comprehensive presentation of all relevant aspects in order to fulfill the basic principles of inclusive design in the 21st century. Only through an in-depth and holistic approach can the vision of truly accessibl e and diversity-oriented architecture become a reality worldwide. To summarize, the overarching question of this work ("Are architectural competitions a good means of ensuring the consideration of diversity dimensions, in particular the "diversity dimension of disability" (DDI)?") will be addressed and the hypotheses verified/falsified. Based on the competitions examined, it can be said that on a superficial level, it appears important to both the competition organizers and the participants to integrate accessibility. However, there is hardly any in-depth discussion of accessibility or the diversity dimension of disability, which is probably due on the one hand to the "comparatively" early phase in the construction planning process, and on the other hand to the fact that there seems to be comparatively little space in competition entries for what is required in the tender, or that the consideration of DDI does not seem "relevant" enough. The hypotheses were: #1: The DDI is generally mentioned ex lege in design briefs; a more in-depth implementation is heavily dependent on the awarding authority and competition participants and cannot be assumed per se. Unfortunately, it should be noted that this hypothesis - at least as far as the competitions examined are concerned - hits the nail on the head. #2: Fundamentally, the term accessibility is considered important, but is very often only used as a superficial buzzword. This hypothesis can also be classified as "correct", as can be seen in the comments already made in this paper.

6.1 Future research and limitations of this study

In the preparatory efforts to produce this work, it became apparent that there is comparatively little work on the "diversity dimension of disability" and competitions. It is therefore advisable to further refine the methodology presented and to apply it broadly to the documentation of competitions in order to gain a meaningful picture of the impact dimension of the competition as an instrument in the genesis of architecture with regard to accessibility. Once a larger database on the subject is available, it can be used to analyze which competitions have achieved particularly good and stringent consideration of these and other diversity dimensions. This in turn could be used to develop better methods for taking these and other diversity dimensions into account in the genesis of architecture. Corresponding analyses could be carried out in detail

with the help of descriptive statistics. The results shown in this document originate from an empirical, largely qualitative analysis. Naturally, aspects of (unconscious) bias cannot be ruled out. Due to time and effort restrictions, the competition evaluations were only carried out by one person at a time, which means that subjective bias cannot be ruled out. Although an attempt was made to work with a standardized procedure (checklist), there is naturally room for interpretation both in the understanding of the source documents and in the analysis work.

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🏆 *reviewed paper*

The Current Use and Limitations of Water Related Digital Twins – a Practical View on Urban Climate Change Adaptation

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1 ABSTRACT

Currently urban areas have to face many challenges. Overall, urbanization, demographic change, digitalization and climate change are main drivers that may directly or indirectly have an impact on the lifestyle and well-being of city dwellers. All drivers are interconnected and together with other sector-relevant drivers they form a complex network, that is often difficult to understand at first glance, and has many points of friction between different interests. For example, a growing urban population needs more space for housing areas which increases sealed surfaces and reduces natural groundwater recharge. Due to climate change, temperatures are rising (especially over sealed surfaces), also leading to an increasing water demand and rising evaporation rates. Both factors, besides others, influence the natural water cycle. In addition, in many places summer becomes drier, while more precipitation falls in winter times. The number and intensity of heavy rainfall events increases and dry periods are becoming longer. On the supply side, higher demand peaks in summer already pose greater challenges to water suppliers. Heavy rainfall can for example flood facility sites, parts of the critical infrastructure or cause power outages, which can lead to systemic interuptions.

In recent years, also a trend towards “smart cities” can be seen to improve the the quality of life for residents. The idea of the progressing digitalization is to transfer parts of the real word into virtual representatives. Some are referred to as digital twins. However, these digital twins differ in their technical structure, complexity, and target for which they were developed. For years, many city administrations partly already use hydrological or urban climatological models as one form of simplified digital twins.

Against this background, the paper presents and discusses the practical use, main results and lessons learned from case studies using two different hydrological models as digital twins in two German cities. Overall, the experiences from these case studies show that also the use of simplified digital models of a city – or parts of a city – without the need for big-data and monitoring information can be good planning tools to assess plausible results regarding possible future impacts based on climate change on a small scale. However, hydrological models currently are focussing on one or two challenges, only. But, due to the complexity of natural systems with a high number of connected processes, the whole story with interacting multiple drivers is not included totally. Depending on the modelling approach used, it is therefore possible to obtain different results with different models. Therefore, a better combination of several of such digital twins or the development of more powerful tools will be necessary, for example to transform an urban area towards being climate resilient and sustainable.

Keywords: digital twins, complex systems, climate change adaptation, model evaluation, city planning

2 INTRODUCTION

The importance of climate change and its impacts on municipalities (and urban areas) is still increasing (IPCC 2023; Jacob et al. 2021; Kahlenborn et al. 2021). For instance, precipitation patterns are changing across many regions in Germany, with increased winter rainfall and drier summers (Deutschländer and Mächel 2017). Climate change also rises the number and intensity of heavy rainfall events, which have already been observed in certain areas (Papalexiou and Montanari 2019; Fischer and Knutti 2016; Westra et al. 2014). In 2018, a year marked by prolonged periods of very low precipitation and high evaporation rates due to high temperatures, there was a notable increase in such events (Jacob et al. 2021). This trend is in line with the expected effect of rising atmospheric water vapor uptake on convective precipitation causing more intense heavy rainfall events in the future (Giorgi et al. 2019; Giorgi et al. 2011).

Climate change also has far-reaching economic consequences, with damage costs being one of the most significant impacts. In Germany, river floods, urban floods, and flash floods have been the most expensive

extreme weather events to date. They have caused significant damage to buildings, critical infrastructures, and industries, including flooded production sites and disrupted supply chains. The total cost of damages incurred since 2000 is estimated to be more than 70 billion euros in Germany (Trenczek et al. 2022).

Considering the expected impacts and challenges of climate change, it is evident that there is a pressing need to prioritize climate mitigation, adaptation, and sustainability at all levels, especially with a stronger focus on regions and urban areas. This transformation is necessary to achieve a resource-efficient, sustainable, climate-neutral, and climate-adapted society (Jacob et al. 2021). For urban areas, in particular, spatial and urban planning can provide numerous opportunities to implement integrative approaches (Groth et al. 2023; Bender et al. 2022; Groth et al. 2021), which considers social, economic, and environmental aspects holistically to build sustainable and livable urban environments.

In recent years, also a trend towards “smart cities” can be seen as the velocity of data collection has increased. One goal here is the intelligent connection of municipal infrastructure to make city administrations more efficient in improving the quality of life for residents. The idea of the progressing digitalization is to transfer parts of the real word into virtual representatives. Some are referred to as digital twins. Digital twins have been found useful in manufacturing, construction, and maintenance. In contrast, a holistic digital twin of a city would have to cover many fields of action, including all associated technical and human interfaces. For this, extensive data collections and a better systemic understanding of linkages and feedback loops are necessary in advance. As a result, the final product would provide city administrations with a powerful tool. Positive first approaches of such digital twins can for example be found for the cities of Helsinki, Zurich and Vienna (Bender et al. 2023b).

To react proactively to future extreme weather events, many city administrations currently use hydrological or urban climatological models. By simulating different weather scenarios, decision makers get an idea which potential impacts can occur and which adaptation measures promise the greatest overall success. For this, regional climate projections provide a possible view, what and how many weather-related challenges can be expected in the future. Examples of this are the GERICS climate outlook for German administrative districts.[1]

To support municipalities in responding to urban floods resulting from heavy rainfall, the Climate Service Center Germany (GERICS) has conducted case studies in collaboration with stakeholders as part of the “GERICS Adaptation toolkit for cities” (Bender et al. 2017). One main objective of this approach is to demonstrate that also the use of simplified digital models based on a low number of information can serve as an effective planning tool for evaluating potential impacts of climate change for the entire municipality or specific sub-areas, highlighting present and future hot-spots on a local scale. This, in turn, can support the development of adaptation measures that can be planned, justified, and implemented within the context of urban development.

Against this background, the paper presents and discusses the practical use, main results and lessons learned from case studies using two different hydrological models as digital twins in two German cities. The freely available model “River Analysis System” (HEC-RAS), was used to simulate the heavy rainfall runoff behavior in the city of Geesthacht. The software platform “Tygron Engine” by the TAUW GmbH and “HEC-RAS” were applied for a specific hot-spot area in the city of Rostock.

The paper starts with a short overview of the current state of research on heavy rainfall-runoff modeling in chapter 3. The two following chapters describe case studies in the city of Geesthacht (chapter 4) and in the city of Rostock (chapter 5), whereby the Rostock case-study also includes a comparison of two different modeling approaches. Finally, in chapter 6, key findings are summarized and practical recommendations for action as well as further need for research are discussed.

3 THE CURRENT STATE OF RAINFALL-RUNOFF MODELLING

The expanding array and use of hydrological models reflect the diverse range of user requirements in terms of data prerequisites and practical usability. Broadly, these models diverge in their complexity, the extent of encompassed hydrological processes, computer performance, as well as spatial and temporal resolution of input and output parameters (Wagener et al. 2001). The availability of input data holds pivotal significance

[1] https://www.gerics.de/about/news_and_events/news/102260/index.php.en.

in the process of selecting an appropriate model (Clark et al. 2015). The accuracy of model results depends on the model's structure, the quality of input data, and the spatial-temporal precision it entails. Any simplification within the modeling approach inevitably results in a diminished accuracy in portraying processes across space and time (Wagener et al. 2001).

Hydrologic models can generally be classified in the following categories: i) conceptual models, ii) conceptual process-based (empirical) models, and iii) physically-based models (Lees et al. 2021; Guse et al. 2019). Conceptual models are based on straightforward model structures and simplified equations. Exchange of water in the atmosphere, hydrologic constituents, and storage capacities follows the water balance equation, omitting physical processes. Empirical models are based upon non-linear associations between input data and generated results. They are relatively simple in terms of process description, employing a modest number of input parameters. In contrast, physical models adhere to fundamental hydrological principles, integrating physical equations rooted in a profound comprehension of hydrologic processes. These models also account for temporal-spatial fluctuations and are suitable for smaller scales (Sitterson et al. 2017).

Furthermore, data-driven models can be used to simulate rainfall-runoff processes (Herath et al. 2021; Chadalawada et al. 2020; Reichstein et al. 2019; Le et al. 2019). In regions with poor data availability, conceptual models can yield commendable results even with a limited array of input parameters (Kumari et al. 2021). The choice of the model usually depends on the specific natural processes and scope under investigation, the site characteristics, and the spatial-temporal scales encompassed (Horton et al. 2021; Bach et al. 2014).

In most cases, comparative analyses up to now tend to concentrate on river basins (Flores et al. 2021; Lees et al. 2021). Such comparisons generally serve to highlight the advantages and disadvantages of distinct modeling approaches, laying the groundwork for their subsequent application in diverse contexts (Guse et al. 2019; Gao et al. 2016; Koch et al. 2016; Perrin 2001). Although there exist numerous cases of river system modeling, a scarcity of substantial efforts can be observed regarding the use of hydrological models to simulate heavy rainfall runoff in urban areas (Schütze et al. 2021; Wang et al. 2019).

The main challenges for running hydrological modeling in urban environments, are the anthropogenic impacts on the natural hydrological processes, such as soil sealing and compaction elevating surface runoff and reducing groundwater recharge (Cristiano et al. 2017). This leads to a complex system, whereas the exact extent of these interactions cannot always be quantified because they can change on a small scale (Wübbelmann 2023; Salvadore et al. 2015; Fletcher et al. 2013). Consequently, accurate representation of hydrologic processes at an urban scale for heavy rainfall events necessitates elevated spatial and temporal resolutions. In this context, rainfall-runoff models tailored for urban areas tend to segregate vertical and horizontal hydrologic processes, channeling their focus toward surface runoff dynamics.

4 THE GEESTHACHT CASE STUDY

4.1 General aspects – the HEC-RAS modelling approach

In an effort to simulate the runoff dynamics during specific heavy rainfall events within the city of Geesthacht, the "River Analysis System" (HEC-RAS), an open-access model conceived by the U.S. Army Corps of Engineers under the "Hydrologic Engineering Center," was used. Further model specific details can be found at Brunner (2016). During the model's setup, the preparatory phase mandates the organization of input data via a geographic information system – such as ESRI's ArcGIS Pro – enabling seamless integration of elements like buildings, levees, or other flow restrictions.

This distinctive modeling approach seeks to address three primary inquiries: i) identification of current flood-prone zones within the urban area which can be potentially be flooded after heavy rain events, pointing to the immediate need for adaptation strategies, ii) determination of areas within the city where construction measures, such as the densification of existing development, might exacerbate flood risks, and iii) clarifying the flow of surface runoff water during a heavy rainfall event. To this end, scenarios were integrated into the modeling process, varying in terms of spatial extent, the specific intensity of the analyzed rainfall events, and the hypothesized extent of built-up areas.

In close cooperation with project partners from the city administration of Geesthacht, two different scenarios were simulated for the main part of the urban area. The overarching objective was to capture and illustrate the temporal and spatial progression of urban flooding during and after a heavy rainfall event. Within the model framework, precipitation is uniformly distributed across the entire model area.

The first scenario "Historical heavy rainfall" is based on observation data to replicate the impacts of a weather event that happened in the past. Since there are no contemporaneous measurements or observation data available with the required temporal resolution nearby the city of Geesthacht, the remarkable heavy rainfall occurrence of June 15, 2007 – recorded at the closest Boizenburg/Elbe station – was used as a proxy. Throughout the totality of this precipitation episode, a substantial 92.5 mm of rainfall was registered, with the bulk of it (51.6 mm) falling within a single hour.

The second scenario "Severe extreme rainfall" (analog to the 2021 Ahr Valley heavy rainfall event) reflects the destructive power of an exceptional heavy rain event according to the catastrophic event happening in the Ahr Valley in Germany during July 2021, which caused devastation due to its unique topographical characteristics. During that period, 162 mm of precipitation flooded the region in a few hours.

4.2 Results

With respect to the scenario „Historical heavy rainfall" figure 1 (left) shows the surface flow in times of the precipitation peak. The map shows water accumulations of a few centimeters in height, extending over almost the entire road network and a considerable part of undeveloped terrains. Most of these accumulations, although widespread, can be rated as harmless. In particular, water accumulations on roads and steeper terrain segments in the central core of the model area are not continuous, attributable to the ongoing surface runoff. The water thus moves towards the west and southwest, depending on the prevailing topography. The animated temporal sequence clearly illustrates this run-off behavior. Two notable areas are covered on the southern edge of the map: the Elbe River and a reservoir. This results from the model's representation of water accumulations in these areas, although they do not exist in reality, because rainwater is diverted from the Elbe River and discharged into the reservoir, a phenomenon omitted from the model representation.

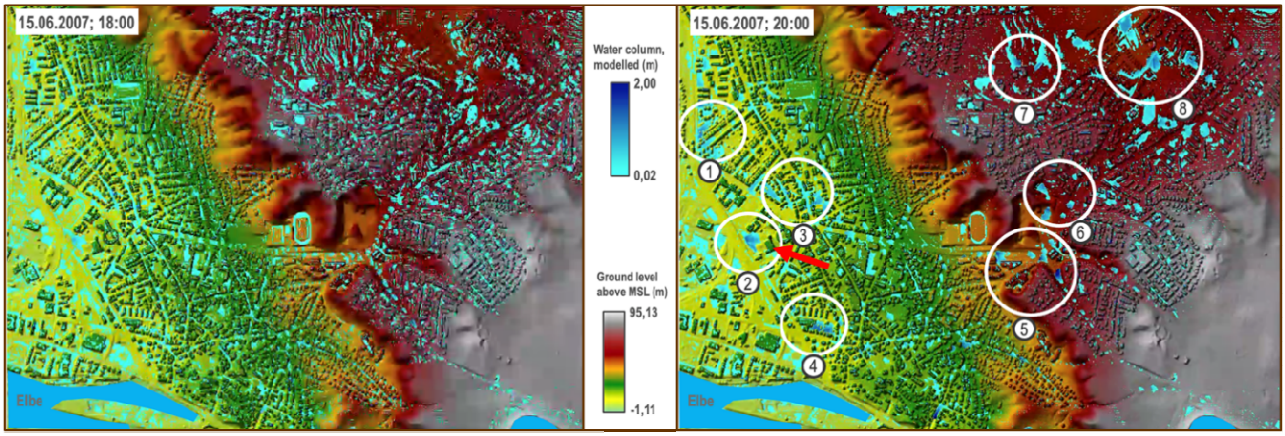

Fig. 1: Simulation results of the rain event "Historical heavy rainfall". The depicted phases encompass the heavy rainfall phase (left) and the subsequent runoff phase (right). Notably, the red arrow demarcates the precise location of the sports hall within the model.

Stormwater, unable to infiltrate the soil, follows roadways, flowing towards lower-lying areas, initially accumulating in depressions. The influence of the sewer system is not included in the model, because its potential effects during such an event are small, because its capacity to take rainwater becomes overloaded in a brief time span. Such a simplification is in line with the application of many hydrological models (Groth et al. 2020). Another reason for the usage of such a simplified model is the lack of precise data on the design of the sewer network, which makes comprehensive modelling challenging.

Based on the available DTM1 data, the current model does contain all operational road culverts or potential drainage pathways. Similarly, inaccessible sites, potentially obstructed by barriers or blockages like littered or clogged culverts, are not integrated into the dataset. In order to improve the model quality, and to enable not only qualitative but also quantitative assessments, an additional on-site mapping for the validation would be necessary. Despite these potential local limitations, the model results show eight potential accumulation

zones (1 - 8) – distinctive circles indicate the flood-prone areas (figure 1, right). In the current version of the model, water depths of up to 2 meters can be seen in these areas, indicating an increased hazard potential.

In the second scenario with severe extreme rainfall, the amount of precipitation was increased to simulate the possible effects of an exceptionally extreme rainfall event. Notably, comparable amounts have been fallen in the summer of 2021 in the Ahr Valley showing that such events can also occur in Germany. Climate change will also increase the probability of such events. To explore potential floodlains within the city under such conditions, the historical precipitation amounts have been approximately tripled in comparison to the first scenario, which makes the temporal development similar to the Ahr Valley event.

The direct effects of more water in the urban area due to the higher precipitation is clearly visible (figure 2, left). In comparison to the first scenario, a larger expanse of water-covered areas emerges initially, while substantially larger volumes of water flow through the streets, towards the Elbe River. This escalation in precipitation quantities leads to more pronounced hydrological effects, increasing the potential for local flooding within the urban area.

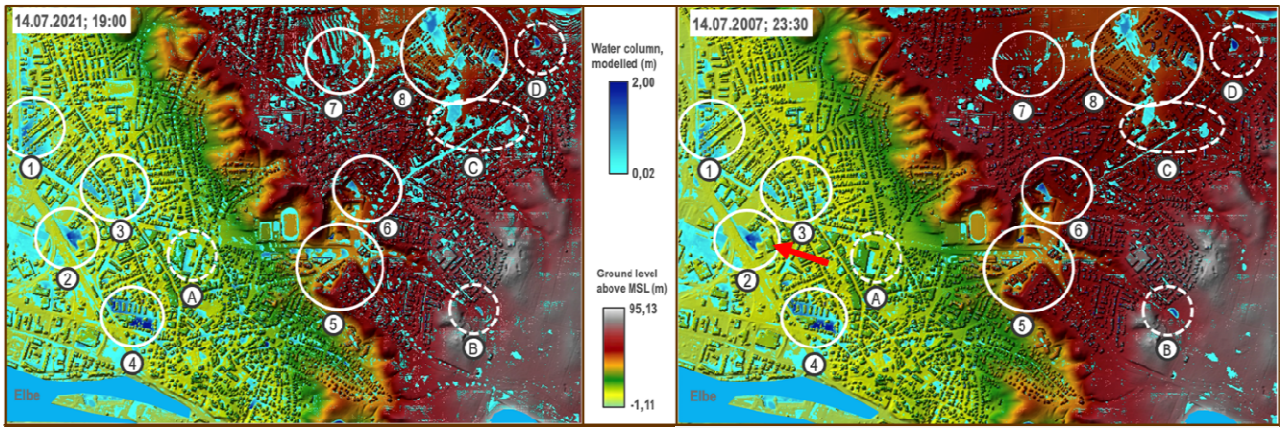

Fig. 2: Simulation of extreme heavy rainfall “Severe extreme rainfall”. Phase during the heavy rain event (left) and the infiltration phase (right). The red arrow shows the location of the sports hall.

The flood-hotspots 1 to 8, which originally appeared in the first sceanrio, now become focal points for significantly larger water accumulations. These accumulations contribute to higher water levels or more extensive flooded regions within these hotspots. Moreover, four new hotspots (A - D) emerge, with water accumulations of about 1 meter (A, C), or localized zones with water depths reaching up to 2 meters (B, D) (figure 2, left). After the primary area precipitation has subsided, water heights of up to 2 meters remain at seven locations (figure 2, right).

Notably, two areas in the western sector of the model stand out, drawing particular attention. In area 2, water accumulation is relatively harmless according to the model, as the water naturally converges into a forested depression, and can gradually seep away without causing any damage. However, special attention should be paid to the sports hall on Grenzstraße (marked with a red arrow), as previous heavy rainfalls have induced moisture damage to its flooring.

Area 4 is an example where re-evaluation of the model is suggested, due to the high degreee of water accumulation. The mapping of missing road culverts and of surface conditions would facilitate a more accurate simulation of water flow directions and potential water quantities in this part of the city. Furthermore, it is advisable to investigate whether past flooding incidents have affected the area in the past.

In the context of this analysis, hotspot B, exclusively evident during the occurrence of the extreme heavy rain event, gives little cause for concern. Embedded in a forested area, it poses a minimal hazard potential. However, within the urban landscape, there are several zones where significant water accumulations can occur, both in terms of area coverage and water depth. Area 6, for instance, where an accumulation zone presently comprises a forested depression, offers the potential for future use as a temporary retention site. To realize this potential, it is crucial to ensure that flood drainage pathes are maintained to allow water flow into the swale. Meanwhile, sections of area 8 and the surroundings of hotpsot area C raise concerns, demanding a comprehensive review of promising adaptation measures, because the model results indicate an increased potential flood risk.

5 THE ROSTOCK CASE STUDY[2]

5.1 The Tygron engine modelling approach

5.1.1 General aspects

The Tygron Engine is as a 3D geodesign platform including cloud computing technology, offering diverse functionalities such as the dynamic computation and interactive visualization of flooding scenarios. The model takes into account a number of influencing factors, including i) infiltration dynamics, ii) evaporation kinetics, iii) groundwater flow phenomena, and iv) the interaction between constructed and natural hydraulic structures. For the Rostock case study, we used a digital terrain model DTM1, affording a grid width of 1 meter. With regard to the precipitation amounts, every cell is individually assigned with a water volume based on the comprehensive dataset from the KOSTRA Atlas German Weather Service (DWD) 2010R of the city of Warnemünde, incorporating the model rain type Euler Type II.

These cells are divided into groups, each assigned relevant parameters like infiltration behavior or roughness factor. The model simulates the interactions between neighboring cells in discrete time steps, taking into account water levels, surface heights, flow direction and other relevant parameters. A high degree of simulation accuracy is achieved through the use of small time steps and a finely gridded spatial layout. In an effort to follow an simplified approach adaptable for all municipalities – especially for municpalities without sufficient information of their sewage system – the sewer capacity was approximated using data according to experience values from other projects. Within the simulation, inflow into the sewer occurs when a grid cell both contains water and coincides with a surface sewer structure. This inflow persists until the sewer reaches its full capacity. Incorporating infiltration into the unsaturated soil zone introduces another option for mitigating surface water.

5.1.2 Results

As an example, we mainly consider a section of the map with the focus on the area around the Holbeinplatz, as illustrated in figure 3. These visualizations contain the essential map representations commonly used in Tygron Engine reports, effectively showing flood depths and flow directions. These representations reveal two vulnerable areas that are prone to flooding. One location is the Holbeinplatz, beneath a railroad bridge, while the other is north of the Werftstraße. In these depicted zones, the simulation shows flooded areas with water depths of up to 5 meters.

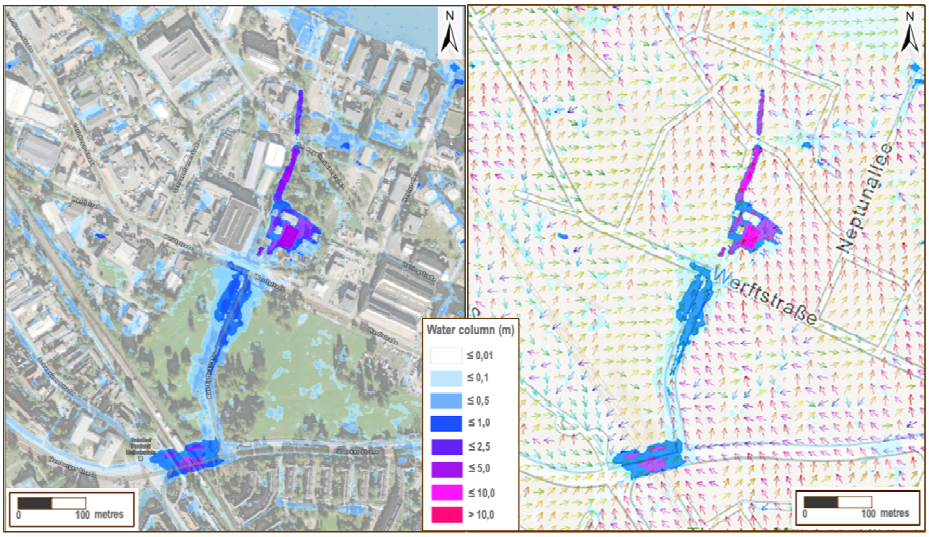

Fig. 3: Left: Flood depths near the Holbeinplatz and Werftstraße. Right: Flow directions of the surface runoff.

[2] The contents and visuals presented within this chapter have been taken from the conclusive reports developed by Tauw GmbH in collaboration with the Climate Service Center Germany (GERICS). These reports titled "Starkregengefahrenkarte Rostock: Studie zur Bewertung des Abflussverhaltens von Starkniederschlägen im Stadtgebiet Rostock mit der Software Tygron" (Tauw 2020) and "Modelloptimierung und alternative Modellansätze Rostock. Vergleich HEC-RAS – Tygron" (Tauw 2022) serve as key references. The contents have undergone modifications to ensure linguistic coherence and have been supplemented to enhance their comprehensiveness.

The modelled flow directions clearly show the dominant course leading toward topographic low points, signifying a likelihood for further water accumulation at these two locations during more intense precipitation episodes. The derived maps highlight the increased vulnerability of the Holbeinplatz, particularly during heavy rainfall events, as it plays a central role within public transportation. In light of the increasing frequency (Bender et al. 2019) and intensity (Dahm et al. 2020) of heavy rain events, proactive adaptation measures are strongly recommended for the Holbeinplatz, emphasizing the urgency of improving resilience.

Around the Werftstraße, the simulation also shows elevated water levels, but only with very local impacts, leading to limited disruptions and potential local damage. Notably, the model unveils water accumulations just north of the railroad bridge, spanning across Werftstraße and Neptunallee. This area's distinct hydrological dynamics are shaped by the presence of multiple road crossings – namely Werftstraße and Am Kayenmühlengraben. An on-site mapping is required to check the reasons for the modeled water columns. Topographical reasons, incorrect boundary conditions for the infiltration rates in the model, but also differences between existing road culverts missing in the model, are among the possible reasons for the modeled results. Independently of the potential need for model refinement, the results clearly indicate zones of increased flood risk. In view of this, it is of utmost importance to make neighboring property and land proprietors aware of these vulnerabilities. Proactive adaptation measures should be considered in this section, highlighting the importance of developing strategies for targeted discharge of surface water into temporary retention areas, where the water cannot cause any damage.

5.2 The HEC-RAS modelling approach

In order to carry out a direct model comparison between the models HEC-RAS and Tygron Engine, we chose a distinct area of the city of Rostock of approximately 4.5 km², using a grid of 5 x 5 m. To ensure consistency, both models are built with the same input data and without a detailed sewage system, as well as neither “missing” culverts nor pumps were considered. For the incorporation of infiltration, the curve-number (CN) method was applied, estimating the extent of infiltrated precipitation as a function of cumulative precipitation amount, soil sealing, land use, and soil moisture. In order to approximate the Courant criterion, calculation intervals were set at 2 seconds. Consequently, the computational iteration duration for HEC-RAS was about 10 minutes and 30 seconds per run, adhering to these specified parameters.

When performing simulations, time intervals can be set manually, serving as default settings for computations. The choice of these time steps, ranging from seconds to several minutes, depending on the processing capability of the computer and the time interval to be analysed. Despite maintaining identical model parameterization, the selection of time step length has a direct influence on the model outputs, whether in the form of map displays or chronological sequences presented as videos.

Figure 4 shows two snapshots from another project capturing the same point in time during the simulation of a heavy rainfall event. The only distinguishing feature between both approaches is the configuration of the time steps, set at 1 minute and 10 minutes, respectively. However, the visual representation differs significantly. In the model with 1-minute time steps, a lower water presence within the model areas is evident at first glance, with all water showing a lower extent. Furthermore, the identified hotspots have shallower water depths. Nonetheless, the accompanying scales illustrate that this scenario actually culminates in a higher peak for water depths when contrasted with the entire model area. In both cases, surface runoff is represented as fragmented non-contiguous flows, attributed to the Courant condition not being met. As a result, spatially restricted water accumulations occur.

This phenomenon – once again – highlights that model results should always be scrutinised, because depending on the model parameters selected, effects can occur – in this case flood heights – that are based only on mathematical boundary conditions. In this case such a phenomenon can be significantly improved by reducing the time steps to seconds.

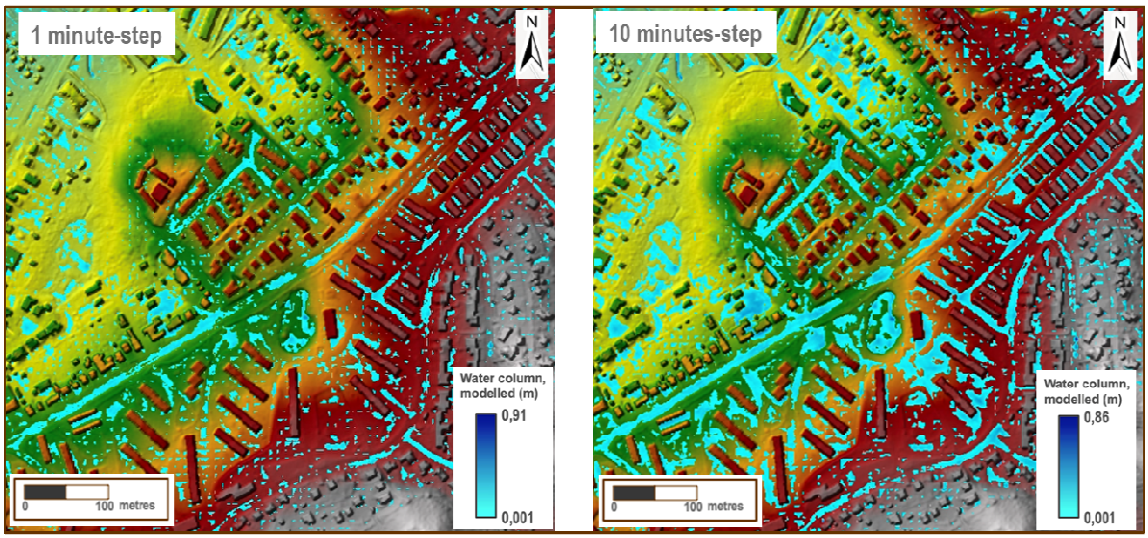

Fig. 4: HEC-RAS calculations with different time step configurations. Left: Time step 1 minute. Right: Time step 10 minutes.

5.3 Model comparison

In line with the increasing number of precipitation-runoff modeling efforts focused on heavy rainfall events, various map representations are available, depending on the specific modelling approach. As the interpretation of results is not always entrusted to modeling experts, this case study example presents the results of different models partly using identical input parameters. To enhance comparability, the modeling was conducted by the same experienced team, minimizing the influence of individual modelers as much as possible. Table 1 provides a summarizing comparison of the technical boundary conditions and key model input parameters. As an example we compare the modeled water depths in the Holbeinplatz and Werftstraße areas in Rostock (figure 5). In both model simulations, the primary flood-prone areas are observed around Holbeinplatz, particularly below the bridge, and south of Werftstraße. The spatial extent and water depths exhibit rough similarity, although the Tygron modeling indicates slightly larger water depths. The main differences are evident in areas somewhat distant from the primary hotspots.

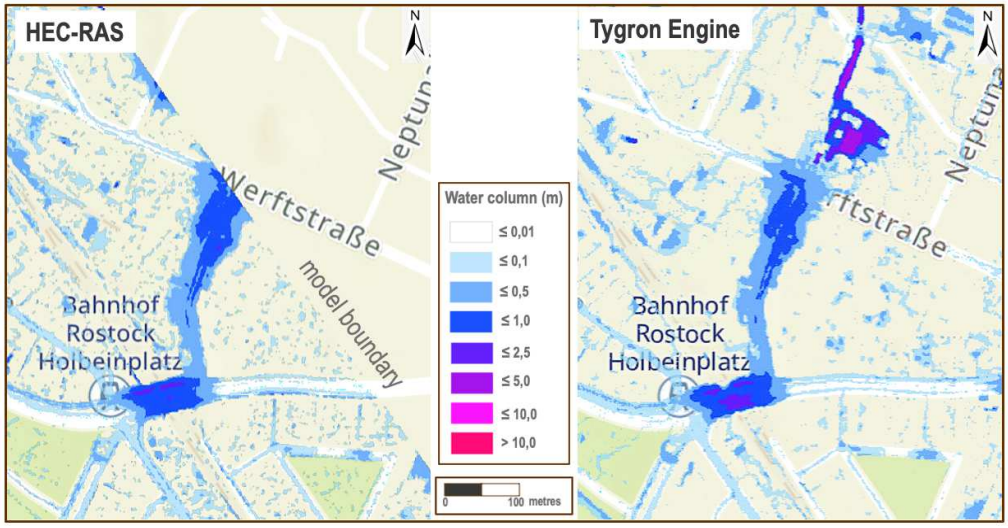

Fig. 5: Results from different model simulations. Left: HEC-RAS. Right: Tygron Engine.

The HEC-RAS result depicts a more “restless” scenario, characterized by numerous small delineated water accumulations. Conversely, the Tygron result shows larger continuous patches of water, attributed to its smaller time steps and the automatic stabilizer function. Overall, the Tygron modeling shows lower total water columns compared to HEC-RAS, particularly in areas with minor water accumulations, which is due to the incorporated channel capacity consideration. However, the model results also illustrate that in areas where this capacity is exceeded, Tygron exhibits higher water levels.

Input parameters and boundary conditions	**HEC-RAS (Rostock)**	**Tygron Engine (Rostock)**
Initial water levels	No	No
Hydraulic structures	No	No
Soil parameters	Yes	Yes
Roughness factor	Yes	Yes
Topography	Yes	Yes
Grid size	5x5 m, flexible mesh possible	1x1 m, only fixed mesh possible, 315 million cells
Total size	4,5 km²	9-10 km²
Boundary conditions	Adapted to road course	Adapted from the largest model
Infiltration	Calculation with the curve number method, where the land use determines the infiltration rate. Land use determines the infiltration rate; no further adjustments were made.	Dependent on the K-factors of the ground surface and the soil properties. In the RSAG area: Adjustment 0.06 m/d in the track area.
Sewer system	No	With averaged capacity of 10.82 mm/h under "street" cells
Evapotranspiration	No	Yes, minimal
Time step length	2 seconds	0,114 seconds
Rainfall event	43,5 mm/h	43,5 mm/h
Maximum discharge velocities	20 m/s	1-2,5 m/s
Computing time per run	10 min 30 sec	1 min
Flood heights	Up to 2,5 m	Up to 10 m
Surface runoff	In a chain of water accumulations.	In a chain of water accumulations.
Expected costs	0 to 10 k€ (including validation and one scenario)	15 to 25 k€ (including validation and one scenario)
Computer capacity	For modelling: Desktop PC or Laptop For use of results: Desktop PC or Laptop	For modelling: Access to supercomputer (proprietary) For use of results: Desktop PC or Laptop
Staff skill requirements	For modelling: Hydrological modelling skills; not required when modelling is done by a company. For interpretation: Basic hydrological understanding and modelling expertise would be an advantage	For modelling: not required. For interpretation: Basic hydrological understanding and modelling expertise would be an advantage

Table 1: Input parameters and boundary conditions.

Looking at the area southwest of the Schwanenteichpark in figure 6, the contrasting characteristics of the two model approaches are also evident. In the HEC-RAS modeling on the left, water accumulations are evenly distributed across the area, with generally shallow water columns of just a few centimeters. However, when using the Tygron model many of these water patches disappear, as the sewer model component removes a defined water volume from the surface. At first glance, this creates a smoother appearance. However, in places where water accumulates, higher water depths are observed despite the smaller time step. Moreover, new flood areas are formed compared to HEC-RAS, such as in the western region of Kuphalstraße. This divergence could be attributed to the fact that the analyzed area lies in close proximity to the model boundary of HEC-RAS, where hydraulic conditions are more strongly influenced by the given boundary conditions of the model. So it can happen at some points, that surface water is forced to flow out of the model. Therefore, when interpreting map representations, it is crucial to focus on areas located more in the central part of the model area whenever feasible to ensure reliable interpretations without impacts from the model architecture.

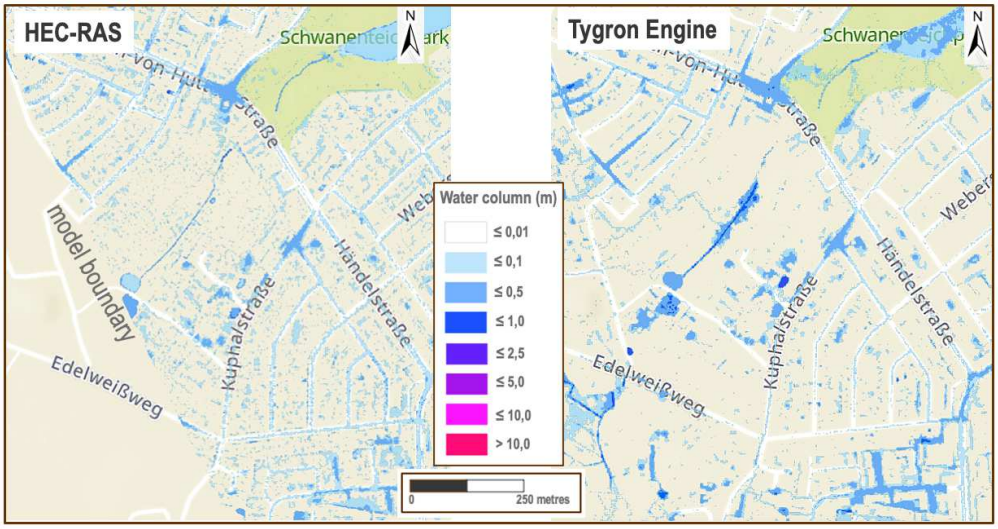

Fig. 6: Results from different model simulations. Left: HEC-RAS. Right: Tygron Engine.

6 CONCLUSION

The comparison between two hydrological models highlights their general usefulness in creating hazard maps for heavy rainfall events. Both approaches provide essential tools to identify areas that are potentially affected or at risk of flooding. Furthermore, these maps can be used to locate flow paths within urban areas, and to visualise significant hotspots.

Practical results and experience indicate that HEC-RAS offers a feasible way to quickly generate initial estimates of runoff behavior during heavy rainfall events (Wübbelmann 2023; Bender et al. 2023a). These calculations can be performed on a standard PC or laptop. With numerous customizable settings, the model can be tailored to individual requirements based on available data resources. It is ideally suited for the detailed analysis of small-scale areas and can also be applied to model smaller cities. Thanks to its relatively short computation times and hardware requirements, it enables rapid simulations of scenarios such as land use changes or the impact of new constructions on runoff behavior.

The commercial Tygron geodesign platform operated by engeneering companies stands out for its combination of fast computation and high-resolution output. The program automatically adjusts certain conditions to ensure robust numerical modeling, thereby achieving high-quality simulations, particularly in terms of surface water flow behavior. The model uses regional to local parameters and characteristics, such as soil types, for individual process calculations. However, it is not designed to account for small-scale processes like the influence of soil moisture on infiltration behavior. Due to its computing power, Tygron is also suitable for larger areas, including entire cities. Its 3D visualizations offer compelling materials for decision-makers to effectively raise public awareness about flooding issues.

In general, there is a need to optimize the process of “awarness creation – implementation of prevention measures – crisis communication”. This includes the improvement of early warning systems, for example due to a combination of regional climate information, data-collection from historcial events, and on-site monitoring using of sensors or satellites. There is also significant potential in providing comprehensive and area-wide digital models of municipalities, facilitating efficient heavy rainfall runoff modeling. However, it is important to also consider risk associated with digitization. Critical infrastructures, such as energy supply, information technology, and telecommunications, are expected to become increasingly vulnerable to the impacts of more frequent and intense extreme weather events (Groth et al. 2023). In order to take protective measures at an early stage, the hydrologcial models can also be used to check which components of the critical infrastruchture are – currently and in the future – located in vulnerable areas. However, in addition to the modelling activities also monitoring should be considered. This includes the regular updating of input parameters – e.g. land use or observed flooding – as well as the regular functionality check of components that affect runoff – such as blocked gullies or overgrown drainage ditches.

Overall, the experiences show that also the use of simplified digital models of a city – or parts of a city – without the need for big-data and monitoring information can be good planning tools to assess plausible results regarding possible impacts of climate change on a small scale. Based on this, first adaptation measures can be planned, tested in a simuation, justified, and implemented in the context of urban planning and development. Irrespective of the model results, preventive measures such as the large-scale unsealing of surfaces, increasing the proportion of green spaces and the creation of temporary retention areas and flood drainage paths have a positive influence on the flooding behaviour.

However, due to the complexity of natural systems with a high number of connected processes, the effects of such measures on the local scale and on the whole system can be answered – sometimes in parts, only – by the use of these models. Depending on the model used, local model results may vary, but the location of the most important hot spots is generally recognised. To increase the informative value of the models, either the results of different models can be combined or more complex models - which also require more input data - can be used, for example to transform an urban area towards being climate resilient and sustainable. Thereby also the possible implementation time and cost of adaptation measures (including the regular maintenance) as well as the cost of using different modelling approaches needs to be taken into account.

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The Human-Based Sustainability: a Responsive Approach towards Cities Redevelopment

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1 ABSTRACT

Cities are complex and dynamic systems facing multiple challenges, such as environmental degradation, population growth, urban sprawl, social inequality, economic instability, and others. Environmental and physical sustainability approaches are insufficient to face these challenges. Cities need to adopt a more sustainable and flexible human based approach that takes into account the needs and aspirations of their residents, as well as paying attention to applying simple affordable environmental techniques and systems. The paper presents a new vision for achieving success when transforming existing cities into sustainable cities by creating a human-based sustainability model through an applied study.

Firstly, it reviews recent literature on the concept of human-based sustainability strategies, presenting the goals of sustainable development, priciples and process for transforming existing cities into sustainable cities. Presenting some examples of sustainable projects that have failed, analyzing them and mentioning the reasons. The paper's novel perspective emphasizes the crucial role of the humans in achieving sustainability. This comes after it has been established that the mere application of advanced environmental techniques is insufficient for transformation success. This perspective serves as a starting point to underscore the importance of human-based approaches in sustainable practices. Seven theories of human needs will be discussed to identify key needs that can influence people's shift towards sustainable behaviour. This will serve as a prelude to highlight the significance of merging five crucial elements, known as the 5A elements (attractiveness, accessibility, awareness, affordability, availability), with sustainability strategies.

Finally, the theories of human needs and the five elements that instigate behavioural change will be amalgamated based on their priorities and ralative importance, so as to set up a human-based approach model to be applyied to existing Egyptian cities for sustainability tranformation. This will be followed by a conclusive summary as a guide to practical application, as this process demonstrates the significance of the human factors in achieving sustainability, as opposed to solely relying on modern physical and environmental sustainability technologies.

Keywords: human needs, human behaviour, humanitarian actions, human based sustainability, transformation

2 HUMAN-BASED SUSTAINABILITY

Human-based sustainability is a new axis that focuses mainly on changing people's behaviour towards sustainable behaviour instead of focusing solely on applying new technology and technologies. Many international experiences have proven that the application of modern technology alone does not guarantee the success of sustainable projects, as the wrong use of people is a sufficient reason for the failure of sustainable projects. For example, implementing public transportation systems does not mean that people will use them and dispense with their private cars. Likewise, implementing the idea of energy-efficient homes does not mean that people will be able to use them in the manner intended to conserve energy, and other examples. Because of this, it was necessary to focus on how to change people's behaviour towards sustainable behaviour to ensure the success of sustainable projects. The paper methodology will be processed as in (Figure1).

Figure 1: Research Methodology Skeleton. Source: (Authors, 2023).

3 SUSTAINABLE CITIES

It is a concept based on creating a new shape for cities by achieving economic growth through an economic base that does not deplete natural resources through irrational use and does not pollute them, and it also adopts the principle of reusing the product through recycling as an input in another production process while recovering the energy invested in this product (Locke, 2021).

Sustainable cities achieve social justice for their residents as they reinforce the concepts of democracy, self-reliance and participation in decision-making, as the sustainability of the city comes from the society's dependence on itself by meeting the basic needs of its members, ending the gap between the rich and the poor, and the different levels of income, and ensuring Participation and accountability, ensuring the minimum acceptable quality of life for all members of society, and using technical techniques compatible with their local conditions (Locke, 2021).

The sustainable city is a green environmentally friendly city in which the absorptive capacity of local resources and ecosystems is balanced by raising the efficiency of resource use and achieving the least possible amount of polluting outputs and preventing pollution by reducing waste. It is a zero-carbon city and thus contributes to reducing carbon dioxide production. And other organic compounds that lead to an increase in the severity of climate change. And it works to use structural transformations to reduce the use of fossil fuels to a minimum, and to increase reliance on renewable energy resources such as wind energy, solar energy, wave energy, geological energy, and others (Monga, 2020). Human Factor can be integrated in sustainable cities as shown in (figure 2).

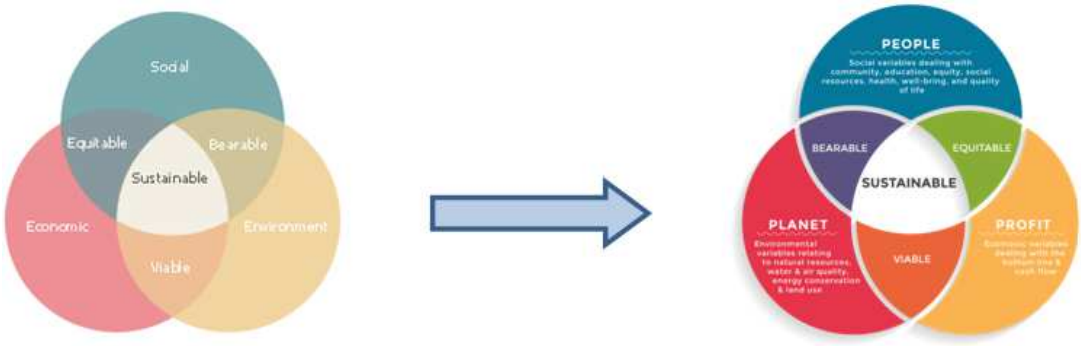

Figure 2: Sustainable City. Source: (Venn Diagrams, https://conceptdraw.com/a2058c3/preview)

These important structural transformations not only require integrated industrial ecological systems to manage and recycle liquid, solid and gaseous waste, while also requiring cultural shifts in consumption patterns, transportation and entertainment. For example, sustainable cities are characterized by a (relatively) compact fabric in order to reduce the travel distances between work, housing and services, and thus reduce energy use in transportation, and thus requires planning land uses in a way that enhances these perceptions (Monga, 2020) as shown in (figure 3).

Figure 3: Pillars for achieving sustainability of cities. Source: (The United Nations, 2013)

In this paper, the social aspect will be in-depth and linked with an important axis, which is human-based sustainability which will include two major factors: Theories of human needs and 5A's factor (Availability, Accessibility, Attractiveness, Affordability, Awareness), to reach a successful methodology for transforming urban cities into sustainable cities.

4 PRINCIPLES AND PROCESS FOR TRANSFORMING EXISTING CITIES INTO SUSTAINABLE CITIES

According to Crane 2020, urban cities can be transformed into sustainable cities by balancing all the elements of sustainability (the social element, economic element, and environmental element), so that each of them aims to mitigate the environmental impact of the city. The idea of converting to a sustainable city aims for the city's residents to reduce the city's necessary inputs of water/energy/food, etc., and reduce its output of gases/waste/polluting materials. The city provides the needs of its residents at the present time without affecting the needs of future generations of its residents. One of the most important foundations for transforming urban cities into sustainable cities is to transform the city from an energy-consuming city to a city that produces it. Therefore, the goal is to reduce the energy derived from petroleum fuels and to use renewable energies. Applying the theories of water efficiency education, rainwater collection and reuse, sustainable and collective transportation instead of individual transportation, which reduces gas emissions Harmful, connected pedestrian paths to reduce the use of environmentally harmful transportation (Crane, 2020). This is in addition to changing people's behavior towards sustainable behavior for the success of the process as shown in (figure 4).

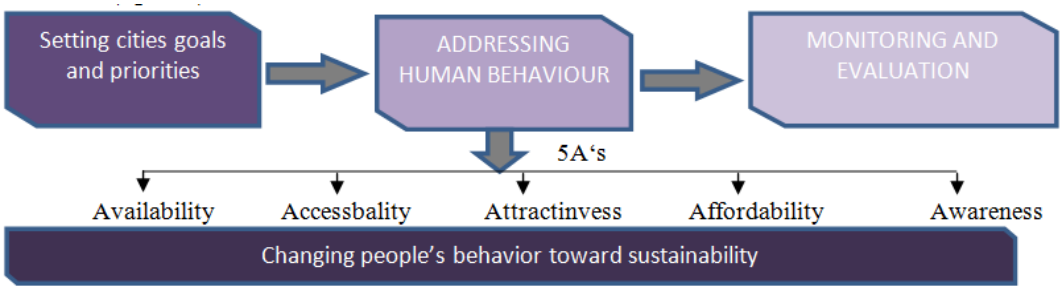

Figure 4: Holistic approach, Transforming existing cities into sustainable cities. Surce:(Author, 2023)

Some cities aim to reduce carbon emissions by creating walkable green neighbourhoods or by tracking emissions by developing high-tech greenhouse gas inventory systems. An example of this is the United Arab Emirates, the cities of Masdar and Dubai working to integrate green spaces, zero emissions targets, urban agriculture and water reuse systems. Nairobi, Kenya, uses modern slum mapping techniques to help planners provide better services (Hawley, 2014). Curitiba, Brazil was the first to introduce the Bus Rapid Transit (BRT) system, and it has since been widely adopted. He took 'human ecology' methodologies for urban sustainability, in addition to creating 52 square meters of green space for every person in the city. Bogotá devised an integrated Trans Milenio transportation strategy to counteract congestion in the city starting with the Bus Rapid Transit system and its four lines extending 55 kilometres above the city (Hawley, 2014). Another example, the Caribbean region has the first sewage treatment plant, as Port is one of the largest cities in the world that does not have a sewage system, this treatment plant with trucks collecting sewage from canals, private sewage pits and latrines (Hawley, 2014). However, with many cities trying to transform some of their areas into sustainable areas and trying to implement sustainable projects, many of these projects faild when implemented on the ground due to failure to take into consideration the behavior and needs of people, but rather only modern technology was applied.

5 VARIOUS FAILURES IN URBAN SUSTAINABILITY PROJECTS

The previous aforementioned projects were very successful on paper, but when implemented on the ground, this was not the case, as many of them proved to be failures. (Table 1) compares the projects and the reasons for the success of some and the reasons for the failure of others to extract the most important points. As all the projects mentioned in the table proved successful when they were planned on paper, but when implemented they proved to be failures, and the reason for the failure of all these projects was the same reason, which is to focus at the time of planning on implementing technology and applying modern technologies only and not looking at The needs and requirements of the population and how to change their behavior towards sustainable behavior, which led to the incorrect use of modern technology implemented in these projects, and thus energy was wasted, as well as people not using the applicable means of public transportation and continuing to use their private cars due to the lack of any incentives that motivate them to choose the sustainable option.

COUNTRIES	NEW SUSTAINABLE PROJECTS	
	SUCCESSED on paper	FAILED when implemented
Chicago	Has the second largest public transportation system in the United States (Chicago Transit Authority, 2017). Chicago has been rated the most bike-friendly city in the country.	More than 70% of the population drives their own cars, and only a small percentage use public transportation.
Phoenix Arizona	The opening of the Metro Valley railway, in addition to the construction of a pedestrian path and a bicycle path surrounded by landscapes for shading.	The field study showed that residents still use their own cars, and only a few use the metro or bikes (Hurtado, 2016).
City of Linz, Austria	The implementation of the Solar City project, which won several awards for sustainable urban development, as it is characterized by sustainable design, energy-saving buildings, solar panels for district heating and renewable energy generation, and the provision of public transportation stations (Lins, 2009) to motivate residents to leave driving and go to public transportation. This project received many awards due to the sustainable technical solutions that were presented on paper.	It did not succeed in achieving sustainability as it was planned. As the post-occupation evaluation deals with the behavioural and social aspects of the building occupants and how they use sustainable technologies in it, but the pre-occupation evaluation deals with the technical aspects of the building only (Wener, 1989). Follow-up showed that only 15% used public transportation, while only 1% used their own bikes or walked (Lins, 2009), and more than 80% still use their own cars. Also, because a large percentage do not understand how to use ventilation and heating systems, this led to inefficient use and waste of energy that could have been preserved.

Table1: Reason of failer of some sustainability projects. Source: (Author, 2023)

With the previously mentioned examples of some cities that are trying to create sustainable projects, many of these projects have proven to fail for several reasons, including people's behavior, as the largest percentage of people still use their own cars and do not use public transportation. It also turns out that many people use energy-efficient homes incorrectly, which increases energy consumption and does not reduce it as planned. This is in addition to the absence of achieving the five elements that help guide people in choosing the sustainable option. People choose the easiest and least expensive option for them, regardless of the interest of the city. Therefore, sustainable options must be attractive to people and more economical than other non-sustainable options, and sustainable options must be available and easy to access so that people do not struggle to access them, and in addition to being attractive so that people turn to them and leave unsustainable options. Hence, we conclude from the previous examples that the reason for the failure or success of sustainable projects is several factors united together and not just the application of new technology and techniques. Therefore, it is necessary to study people's behavior through seven theories that will be listed and analyzed, as well as studying the most important elements that help change people's behavior towards sustainable behavior, which is called the 5A's, and then integrating all of the above to conclude the most important success points when transforming urban cities to a sustainable city.

6 HUMAN NEEDS THEORIES

6.1 Maslow theory

divided human needs into five needs: first, physiological needs, such as shelter, rest, and food; second, safety needs, which is the need for individuals to feel safe and secure; third, social needs, such as the desire of people to form acceptable relationships with others; fourth, self-esteem needs, which is the need for individuals to feel safe and secure. With appreciation and respect, fifthly, self-actualization needs, which are individuals' desire to feel self-actualization, accomplishment, and independence (McLeod, 2018).

6.2 McClelland's achievement motivation theory

McClelland divided individuals' need motives into three motives: firstly, the power motive, which is the individuals' need to feel powerful, secondly, the achievement motive, which is the individuals' need to achieve and strive for success, thirdly, the affiliation motive, which is the individuals' need to feel belonging and form friendships, and his feeling that he is accepted in society (Kurt, 2021).

6.3 Adams' equity theory

according to Green 2022, Adams' equity theory states that people seek to preserve their input and are motivated to compare their results with the results of others in similar situations.

6.4 Alderfer's ERG model

tried to combine the five levels in Maslow's theory to form three groups existence, relatedness, and growth. Existence and relatedness, which equals the third and fourth levels of Maslow's theory, growth, which equals the fourth and fifth levels, such as respect and self-awareness (Kurt, 2023).

6.5 Findlay theory of human needs

In which four human needs were identified: firstly, psychological needs, such as providing various basic services to people, such as education, health, care, and others. Secondly, natural needs, such as physiological needs for food, drink, safety, and others. Thirdly, needs for self-realization through appropriate work and Ability to afford costs. Fourthly, social needs such as people's sense of belonging and interaction with society (Findlay, 1982).

6.6 MAX-NEEF Theory of Human Needs

according to Gasper 2022, this theory indicates that people's needs are variable needs that depend on other factors such as culture, environment, life efficiency, etc., and are not fixed needs with a hierarchy, as Maslow indicated. This theory indicates that human needs are divided into two parts: value and existence. Value includes participation, creativity, protection, and freedom. Existence includes interaction, possession, and action.

6.7 Costanza's theory of paraphrasing human needs

This theory reviews people's needs as follows: the need for security, which includes security inside and outside homes and safety from crime. Second, basic living needs such as food, environmental services, shelter, clean air, and health care. Third, affection, which is achieved through tolerance, empathy, community participation, and citizenship. Fourth, understanding, through obtaining intuitive and rational information. Fifth, spirituality, through participation in society and access to nature. Sixth, creativity, through artistic and emotional expression and imagination. Seventh. Freedom and finally identity (Costanza, 2007). Through the previously mentioned theories, human needs can be divided into two basic parts, the psychological aspect, which includes personal feelings that affect the behavior of individuals, and social aspect, which includes social relationships between individuals in society and their sense of belonging. (Table 2) will convert these needs to study points that can be acheived in the built environment to ensure that people's needs are met to achieve sustainability.

Aspects/Needs		Theories of human needs	Study points	The scope of its realization in the built environment (Urban design)
Basic needs	Physiological needs	Providing the basic requirements for individuals of security, shelter, food, decent living, and transportation. Clean environment, ventilation, protection from Pollution and green spaces. Environmental services, such as water, clean air and health care.	Provide comfortable accommodation	Providing comfortable housing through housing characteristics, large room spaces, and the interconnectedness of the interior spaces of the residential unit to achieve privacy for its residents, providing comfortable finishing materials for the occupants, providing good insulation materials to protect against disturbance and provide privacy. Taking into account the appropriate orientation of the dwelling to provide appropriate temperatures and natural lighting inside.
			Protection from Pollution, (Environmental services such as clean air).	By providing green spaces in every neighborhood, increasing public transportation to encourage fewer private cars, increasing afforestation, avoiding the passage of private cars in the internal streets between residential buildings, and trying to make public transportation the only thing that passes through the internal streets.
			Provide healthy comfortable environment	Taking care of people's health by providing a healthy walking environment by providing pedestrian paths, bicycle paths, trees, green areas, and gardens.
	Safety needs	Individual's sense of security, safety and protection, maintaining an adequate standard of living and ensuring income. The individual's sense of justice compared to others by achieving security for their home and family. The need to feel safe and secure inside and outside home, sense of security, uniqueness and difference, Privacy, privacy of life.	Individual's sense of security inside dwelling	People feel safe inside the house by achieving privacy for the residential unit by providing large spaces between the facades of the residential buildings and each other, spacing the windows and balconies of the residential units apart from each other, providing green elements and landscaping around the building instead of concrete materials such as awnings, locks, and others. In addition to the distances between residential units should be satisfying.
			Individual's sense of security outside dwelling	Providing safety elements outside the home by providing night lighting in all neighborhoods, in sufficient numbers for good lighting at night, provide clear traffic signs and pedestrian crossings, providing gardens and gathering places in every neighborhood, reducing car traffic on internal streets, especially at night, and can be replaced by public transportation, avoiding streets passing between buildings. Residential areas and replacing them with well-lit bicycle paths and pedestrian paths.
			Density characteristics	Reducing density in residential neighborhoods to increase the individual's feeling of safety, as the higher the population density, the less the individual feels safe. This is done by reducing the number of residential units within one building, reducing the number of floors per building, reducing the number of residential buildings on the same street, and placing parks, green areas, and landscaping instead.
			land uses characteristics	Considering the uses surrounding residential buildings to be uses that do not affect the individual's sense of safety, for example, not placing car garages, blacksmith shops, or heavy equipment repair shops between residential buildings, and being limited to daily use stores such as grocery stores, barber shops, beauty salons, and others.
Self-esteem needs		Individuals' need for appreciation and respect, a sense of self-efficacy, a sense of respect, achievement, and appreciation from others, in addition to self-confidence, Passion, self-esteem, solidarity, tolerance, and generosity.	Improve quality of life	Through the characteristics of the facades of residential units in terms of acoustic properties, the walls are insulated to prevent the transmission of sound from one residential unit to another, and attention is given to the visual characteristics of the facades in terms of aesthetic form, ornaments, and windows with large areas and in an orientation that provides good lighting and ventilation, as well as balconies, and that respect is given to Principles of architectural design in terms of shape and colors. Implementing external painting works for buildings from all sides instead of red stone blocks, in addition to landscaping the roofs, especially for buildings of low height.
			Feeling of familiarity and affection for places	Through afforestation and pedestrian paths, increasing the clarity of the urban environment, which provides an easier opportunity for individuals to roam through it. It makes it easier to get to know others in a healthy environment.
			An adequate standard of living	Distributing facilities and services in a way that meets the needs of the residents of the area by providing all the necessary facilities and various services that people need on a daily basis, including restaurants, cafes, supermarkets, and others.
			Artistic expression and creativity	Respect principles of architecture design. The design of building facades has a tangible impact on individuals' feelings of appreciation and respect or not.
Belonging needs		An individual's sense of belonging to the place they lives in and being accepted by society. Developing friendships and personal relationships. Calm, Fantasy and Relaxation, Equal rights, Familiarity and affection for people and places. A sense of place, belonging and distinction.	Feeling of spatial distinction	By paying attention to the aesthetic values of the buildings, including the aesthetic elements of the facades, the colors and the proportion of the building compared to the neighbors, in addition to the natural environment surrounding the buildings by providing green spaces and landscaping around each unit, especially in the setbacks facing the streets.
			Develop personal relationships, and develop close friendship	Focus on creating and caring for shared corridors leading to residential units, creating gardens and recreational spaces for each group of buildings, and providing suitable places for public gatherings, along with providing play areas for children.
			Equal rights	The equal rights for people increases their sense of belonging, by providing housing units that are similar in characteristics, spaces, style, and aesthetic form of the facades, and that low-income housing is suitable housing that provides all the services available to middle- and high-income housing, whether from Interior spaces or external services surrounding the building.
			A sense belonging and distinction	A sense of belonging and distinction for all segments of society, especially those with special needs and the elderly. For example, providing special pedestrian paths for them surrounded by trees, providing private parking lots for them that are close to the entrances, providing special housing units for them and special elevators to meet their needs, providing special services and entertainment for them, providing pedestrian lines and traffic signs necessary to preserve Their safety when walking on the streets. Also, through the participation of community members in the decision-making process, their sense of belonging increases. This is done through conducting a questionnaire and meetings to present the goals to be achieved and giving community members an opportunity to participate in the decision-making process and express suggestions and ideas.
Social needs		People's desire to join them as acceptable members of a group and their desire for belonging, love, sympathy, and forming acceptable relationships with others. Managing and directing community members. A sense of justice in society comparing members of society in similar situations. Form friendships and close social relationships, the sense of belonging to a social group and the resulting constructive social interactions. Social security, Friendship, social environment, solidarity, cooperation and interaction. Participation in the community, Calm and Relax.	Sense of justice	Individuals' sense of justice increases when they feel equal. Such as all people having access to housing that meets their needs in terms of interior spaces and surrounding services, fairness in the provision and distribution of various services and the ability to obtain them easily, and the ability to choose the appropriate place and the nature and type of housing on the basis of needs and non-discrimination between people. In addition to the characteristics of the dwelling in terms of appropriate architectural appearance and efficient functional performance at various levels of the dwelling.
			Participation in the community	By encouraging social participation in spaces by creating large spaces with shaded seating and landscaping suitable for individuals to gather, and providing appropriate services around them. It accepts the participation of individuals in positive change by expressing opinions, presenting ideas, and evaluating these ideas, instead of each person implementing his idea individually, which distorts the general appearance of the buildings. Knowing that the more individuals feel a sense of belonging, the more their participation in society increases.
			Achieving comfort and calm	This is done by increasing green spaces around buildings, increasing parks and gathering areas, reducing car traffic on internal streets, providing basic services at close distances from residential units, and moving craft workshops and heavy equipment stores outside residential neighborhoods.
Self- actualization needs		Using their abilities, developing and benefiting from them with a sense of independence and dependence on self-realization. The need for achievement and excellence. A sense of self-awareness and the possibility of self-reliance. Quality of life in the area, obtaining work, the appropriate income, ability to bear the cost of residence. Work, Treatment. Creativity, imagination, artistic and emotional expression.	A sense of accomplishment	The individual obtains housing that meets all the basic living requirements and luxury for him and his family, including internal spaces, the interconnection of internal spaces, and external services surrounding the residence.
			self-realization, and self-reliance	This is done by listening to people's opinions and applying them in a way that does not harm the residential neighborhood. Implementing the new ideas proposed for the development of the neighborhood. Holding monthly meetings to present the additions that residents want to implement in order to discuss them, implement them, or find alternative solutions to them, in order to avoid people acting individually that distort the general view.
			Quality of life in the area	Providing a quality of life in the region that meets people's basic and recreational needs. This is done by providing all the services that people need on a permanent basis, in addition to providing facilities, open seating areas, public parks, places for celebrations and gatherings, and children's play areas and others.
			Using individual abilities and developing it	Taking advantage of people's individual abilities. For example, instead of people drawing randomly on walls and buildings, which distort the general view, specific areas are identified, specific drawings are chosen, and they are drawn under the supervision of a supervisory committee in the neighborhood.

Table 2: Theories of human needs as study points and how to achieve it in build environment to achieve sustainability. Source: Author, 2023.

After analyzing the seven theories of human needs, extracting the most important points, and determining how they can be achieved in the built environment to ensure the success of sustainability projects. This is to contribute to setting specific points when transforming current cities into sustainable cities or when establishing sustainable projects within the region. These points can be relied upon directly to ensure the success of sustainable projects., now will move on to clarify five factors called 5A elements (attractiveness, accessibility, awareness, affordability, availability) that in turn contribute to the success in changing people's behavior towards sustainable behavior.

7 FIVE FACTORS TO CHANGE PEOPLE'S BEHAVIOR

From the previously mentioned examples of a group of sustainable projects that proved to fail when implemented on the ground due to people's behavior, it is important to change people's behavior towards sustainable behavior to succeed in transforming urban cities into sustainable cities. The most important thing is to provide sustainable options and reduce the availability of unsustainable options to encourage people to choose sustainable options over others. Researchers found that people's behavior can be changed towards sustainable behavior through five factors called 5A's which are Availability, Accessibility, Attractiveness, Affordability, and Awareness (Stieninger, 2013).

5A'S	Definition	Examples
Availability	Sustainable options must be available, and on the other hand the availability of the unsustainable options must be less, limited, and hard to reach.	Walkable distance to be not more than 500m to the train or bus from any point, with limited parking in all areas in the city to encourage people to use the public transportation.
Accessibility	Sustainable options must be legally and physically accessible, on the other hand the unsuitable options must be less and limited.	Access to public transportation in the city should be facilitated. Improving the use of means of transportation and reducing urban sprawl through growth limits regulated by law.
Attractiveness	Sustainable options must attract the people in the city in terms of quality, safety, beauty, and comfort. On the other hand the unsustainable options must be less attractive and hard to reach.	Train and bus frequencies to be every 5-10 minutes as a maximum. The public stations to be good in naturel lighting and the pedestrian areas to be clean, safe, and comfortable.
Affordability	Sustainable options must be less expensive and affordable comparing to the unsustainable options.	Free crossing paths for buses, trains and public transport. Increased tolls on streets and highways for private cars. Cooperate in the prices of public transport tickets as a monthly subscription value that is less than the weekly or daily subscription.
Awareness	People should be aware of the benefits of sustainable choices from availability, accessibility, attractiveness, affordability, and the benefits of choosing them instead of choosing unsustainable options.	Create awareness of benefits of sustainable options by laws and regulations, information and education (such as car free day), and by obvious design (such as visible subway stations).

Table 3: Five factors to change people's behavior examples. Source: Author, 2023.

COUNTRIES	NEW SUSTAINABLE PROJETCS		Reasons for failure	Fail in achieving 5A's approaches				
	SUCCESSED	FAILED		Availability	Accessibility	Attractiveness	Affordability	Awareness
Chicago	-Has the second largest public transportation system in the United States (Chicago Transit Authority, 2017). -Chicago has been rated the most bike-friendly city in the country.	More than 70% of the population drives their own cars, and only a small percentage use public transportation.	-Driving is still attractive to the population			✓		✓
			-Residents see no advantage in taking the train or public transportation			✓		✓
			-Distances from public transportation stations is far		✓			
			-There are no fines or penalties for those who use their own cars daily					✓
			-There are no incentives for those who use their own bicycles or public transportation.			✓		✓
Phoenix Arizona	The opening of the Metro Valley railway, in addition to the construction of a pedestrian path and a bicycle path surrounded by landscapes for shading.	The field study showed that residents still use their own cars, and only a few use the metro or bikes (Hurtado, 2016).	-Driving is still attractive to the population			✓		✓
			-Residents see no advantage in taking the train or public transportation			✓		✓
			-Distances from public transportation stations is far		✓			
			-There are no fines or penalties for those who use their own cars daily					✓
			-There are no incentives for those who use their own bicycles or public transportation.			✓		✓
City of Linz, Austria	The implementation of the Solar City project, which won several awards for sustainable urban development, as it is characterized by sustainable design, energy-saving buildings, solar panels for district heating and renewable energy generation, and the provision of public transportation stations (Lins, 2009) to motivate residents to leave driving and go to public transportation. This project received many awards due to the sustainable technical solutions that were presented on paper.	When evaluating the project after the works, it showed that it did not succeed in achieving sustainability as it was planned. As the post-occupation evaluation deals with the behavioural and social aspects of the building occupants and how they use sustainable technologies in it, but the pre-occupation evaluation deals with the technical aspects of the building only (Wener, 1989). Follow-up showed that only 15% used public transportation, while only 1% used their own bikes or walked (Lins, 2009), and more than 80% still use their own cars. Also, because a large percentage do not understand how to properly use ventilation and heating systems inside homes with energy-saving technologies, this led to inefficient use and waste of energy that could have been preserved.	The focus was on new technologies without focusing on the needs of users and their requirements to change behaviour.			✓		
			The success of sustainability projects does not only depend on modern technologies and innovative technical design, but also depends mainly on the needs, preferences and behaviour of users.					✓
			Driving is still attractive to the population			✓		✓
			Residents see no advantage in taking the train or public transportation.					✓
			Distances from public transportation stations are far.		✓			
			There are no fines or penalties for those who use their own cars daily.					✓
			There are no incentives for those who use their own bicycles or public transportation.			✓		✓

Table 4: The relationship between the failure of sustainable projects and failure to achieve the 5A's. Source: Author, 2023.

After presenting the five factors that affect people's behaviour, the previously mentioned examples of sustainable projects that have proven to fail when implemented on the ground will now be analysed, with an analysis of the causes of failure and a comparison to the extent to which the five factors have been applied to change the behaviour of the aforementioned people or not. As shown in (Table 4).

8 SYNERGY BETWEEN SUSTAINABLE HUMAN BEHAVIOUR AND THE USE OF NEW TECHNOLOGIES

Synergy can be created between the use of new technology and sustainable human behavior to achieve overall sustainability in cities.

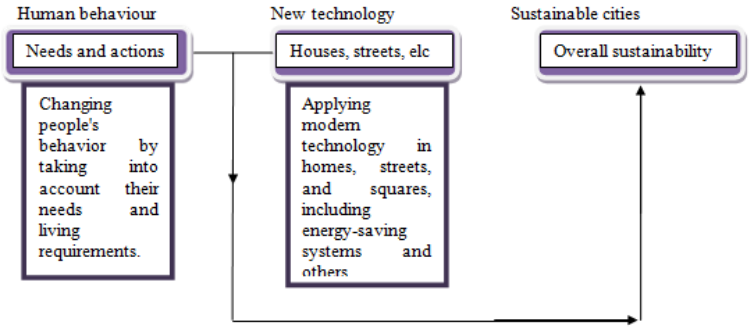

Figure 5: Synergy between human behaviour and the use of new technologies. Surce:(Author, 2023)

As shiwn in figure 5, intensive awareness courses can be conducted to educate people on how to use modern technologies implemented in homes, for example, and tests can be conducted for the residents of the home to ensure their ability to use modern technology implemented at home. Awareness and education can also be increased through television advertisements to ensure that this important awareness information will be seen by every home in the city, thus increasing the level of awareness among people so that their behavior changes to sustainable behavior and thus they are able to make the correct use of the technology implemented.

9 CONCLUSION

It was cocnclued that applying the new technology alone is not sufficient for the success of sustainability projects. Examples have proven that implementing sustainable projects alone without looking at the needs of the population and their behavior results in the failure of these projects. For example, implementing a public transportation system does not mean that people will use it and dispense with their cars. In particular, the application of energy-saving home systems does not mean that people will use them in the correct way that saves energy. On the contrary, their incorrect use can cause greater energy consumption than expected. Therefore, the solution to the success of sustainable projects is to change people's behavior towards sustainable behavior. It is necessary to know people's needs and requirements by analyzing the seven theories of people's needs and knowing how to apply this when transforming urban projects into sustainable projects to ensure their success. The five elements also contribute significantly to changing people's behavior towards sustainable behavior and encourage people to choose the sustainable option even if they have an unsustainable option in front of them, and this is what has been proven from the examples that were presented. Therefore, changing people's behavior towards sustainable behavior is the solution to ensuring sustainability projects, and not just applying modern technology without looking at the needs of the population.

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The Implementation of Artificial Intelligence in Project Management

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1 ABSTRACT

Successful Project Management plays a more than ever before central and crucial role in Smart City Planning and Operations in times of multiple examples of public funded major project, which could only be realized paired by cost explosions and long expanded timelines. The central idea for this research is to implement the current achievements of Artificial Intelligence resulting in innovative Project Management.

The implementation of Artificial Intelligence (AI) in Project Management (PM) has gained significant attention, with roots dating back to 1987 but experiencing recent advancements in machine learning and data analytics. AI has the potential to revolutionize project management, affecting planning, scheduling, risk management, and decision-making. However, its impact on working personnel remains a debated topic.

This thesis explores the impact of Artificial Intelligence (AI) on project management, specifically focusing on its effects on employees. It aims to understand how AI adoption can enhance project management processes, improve certain areas of PM, and boost productivity, while also addressing ethical concerns.

The research combines literature analysis and semi-structured interviews with project managers from Europe and India to investigate the advantages and challenges of integrating AI in project management. It highlights benefits such as workload reduction, better decision-making, and access to insightful data through AI-driven analytics.

Moreover, the study underscores the importance of addressing ethical issues like algorithmic bias, data privacy, and decision-making transparency associated with AI adoption. It emphasizes the need for providing proper training and support to team members to ensure successful AI utilization and mitigate potential opposition or anxiety among project stakeholders.

Overall, this research contributes to the ongoing discourse on AI's role in project management by emphasizing its benefits for employees. It aims to provide insights into AI integration to guide future strategies while prioritizing ethical considerations and ensuring the effectiveness and well-being of project management teams.

Keywords: machine learning, smart city planning, artificial intelligence, project leadership, project management

2 RESEARCH GAP

This paper delves into the integration of artificial intelligence (AI) into project management, focusing on its practical applications and the subsequent adjustments in traditional roles. It contributes insights on how AI can enhance project management practices, reflecting the growing interest among project managers (Holzmann et al., 2022).

AI is acknowledged for its potential to enhance decision-making, resource allocation, and overall project performance, as evidenced by studies by Verma et al. (2021), Ruiz et al. (2021), and Soomro et al. (2019). The importance of considering the impact of AI on workers, particularly in terms of roles, responsibilities, and job satisfaction, is emphasized for effective integration (Fridgeirsson et al., 2021).

While research has examined the benefits of AI in project management, there remains a significant gap in understanding its consequences for employees, including concerns about job displacement and skill requirements (Safdar et al., 2019; Hui et al., 2023; Lee K., 2023).

Recent studies have focused on investigating how AI affects project team cooperation and communication, highlighting the need to understand its impact on coordination, information sharing, and teamwork (Volkmar et al., 2022; PMI, 2023).

This paper aims to bridge this gap by exploring individual perceptions of AI adoption's effects on job roles, skill requirements, job satisfaction, team collaboration, and communication patterns through a

comprehensive review of previous research and interviews with project management practitioners (Chernov & Chernova, 2019; Usher, 2020).

The findings offer insights for organizations incorporating AI into project management, emphasizing the importance of considering employee welfare, professional growth, and teamwork effectiveness. Additionally, the paper suggests how businesses can leverage AI to improve project management practices and achieve better project outcomes.

3 RESEARCH DESIGN

Research Objectives:

- To find factors that influence the role of project managers (human interaction) in the automation era.
- To assess the areas of project management that will be impacted by artificial intelligence
- To develop strategies to adopt automation in day-to-day work

Research Questions:

- How does the application of AI to PM result in a change in power and alter customary roles and relationships within project teams?
- In which specific areas of project management does this potential takeover apply?
- What are the approaches to embracing automation, and how can they be undertaken?

4 INTRODUCTION

Ricardo (1817) and Schumpeter (1943) laid the groundwork for understanding the relationship between technological advancement and economic growth, while Turing (1950) marked a shift in the perception of technical innovation as transformative. Solow (1956) and Swan (1956) further highlighted the impact of computer science advancements, exemplified by Moore's Law, on realizing theoretical ideas.

Edquist (2000) categorized technological innovations, including disruptive technologies like AI, which significantly impact firms' economic activities, necessitating changes in business rules and organizational culture. The New Economy concept emerged, emphasizing the role of digital technology, particularly information and communication technologies (ICTs), in driving economic growth through knowledge elevation.

Project management, as defined by the Project Management Institute (PMI, 2018), involves creating a temporary endeavor to deliver unique results, emphasizing collaboration and successful completion within constraints (Seymour, 2014). The integration of technology into project management, guided by principles outlined by Edkins (2017), emphasizes the presence of competent project managers, supportive environments, and organizational accountability.

While AI integration in project management has led to improved efficiency and effectiveness, questions remain about its impact on project managers and the broader workforce (Costa et al., 2022; Lin et al., 2022). Concerns include the need for skill adaptability and potential job displacement.

Research gaps exist regarding the implications of AI on project management and workforce dynamics, prompting investigations into its benefits, drawbacks, and training implications (Pereira et al., 2021; Lin et al., 2022). Through case studies, literature review, and interviews, this research aims to contribute to the discourse on AI in project management and provide solutions for workforce management.

5 LIERATURE REVIEW

5.1 Integration of AI into Project Management

Artificial intelligence (AI) has emerged as a transformative technology in project management, offering opportunities to improve productivity, decision-making, and efficiency. Key themes in AI integration include:

Data-Driven Decision-Making: AI enables project managers to make data-driven decisions by analyzing large datasets and predicting outcomes (Anantrasirichai & Bull, 2021; Nadimpalli, 2017).

Efficiency and Automation: AI-driven automation reduces project management timeframes by streamlining workflows and implementing technologies like Robotic Process Automation (RPA) (Cordeiro & Cozman, 2024; Nividous, n.d.).

Resource Optimization: AI technologies assess resource availability and project needs to minimize bottlenecks and enhance project performance (Hamm & Klesel, 2021; Lin et al., 2022).

Risk Mitigation: AI-powered systems use machine learning algorithms to evaluate historical data, identify project hazards, and suggest real-time mitigation strategies (Seyedhosseini et al., 2021; Haefner et al., 2020).

Challenges in AI integration include ensuring data quality and accessibility, addressing talent acquisition and skill gaps, and managing risks to security and cybersecurity. Future research should focus on developing AI ethics and governance frameworks, enhancing AI-enabled decision support systems, and exploring models for productive human-AI collaboration.

The structure of AI includes machine learning (ML), which improves algorithms to handle data and create AI models, and artificial neural networks (ANNs), which simulate the brain's neuronal connections. The AI planning process in project management involves problem identification, data gathering and preparation, algorithm selection and training, model evaluation and refinement, and deployment.

The evolution of AI in project management progresses from automation and integration to potentially enabling autonomous project management. However, challenges such as complex environments, technical support, strategic judgments, and limitations in leadership need to be addressed.

5.2 Factors Influencing the Role of Project Managers

Incorporating AI with human managers can enhance productivity and decision-making in various sectors. Project managers play crucial roles in establishing reasonable goals, encouraging teams, building team skills, ensuring accountability, empowering team members, facilitating communication, using tools, adapting to change, and evaluating performance (Harvard Business Review, 2016; PMI, 2019; Pereira et al., 2021).

5.3 Areas of Project Management Impacted by Artificial Intelligence

AI impacts project management decision-making, efficiency, and risk management. Resource allocation, risk management, and project planning are key areas where AI can be applied. Challenges include ethical implications, job displacement concerns, and the balance between leveraging AI's strengths and addressing ethical and reliability issues (Geraldi et al., 2007; Li et al., 2021).

5.4 Technology Adoption Theories, Frameworks, and Models

AI integration promises to improve project management, with businesses using AI being more likely to complete projects on time and achieve ROI projections (PMI, 2023). Challenges in scaling AI adoption include overcoming resistance to change and equipping team members with necessary AI skills. The UTAUT model, Social Cognitive Theory (SCT), Technology Acceptance Model (TAM), Task-Technology Fit (TTF) theory, Organizational Change Theory (OCT), and Human-Computer Interaction (HCI) offer frameworks for understanding and addressing technology adoption in project management (Venkatesh et al., 2003; Bandura, 1977; Davis, 1989; Lin et al., 2020; Poon et al., 2010; Marks & Mirvis, 2011).

Initial Conceptualisation

The model illustrated in the image depicts the relationship between project managers, the adoption of automation strategies, and their influence on effective project implementation, with AI as a central factor.

Influential factors for project managers with AI integration include AI's adaptive features, model complexity, data accuracy, and AI limitations, emphasizing the nuanced interaction between project managers and AI systems in navigating project management in the automation age.

Areas of project management impacted by artificial intelligence include decision-making, efficiency, and risk management capabilities, albeit with concerns regarding ethical issues and effects on job roles. AI's integration reshapes the traditional responsibilities of project managers, augmenting tasks to improve project outcomes while highlighting potential downsides like job displacement and the need for workforce training.

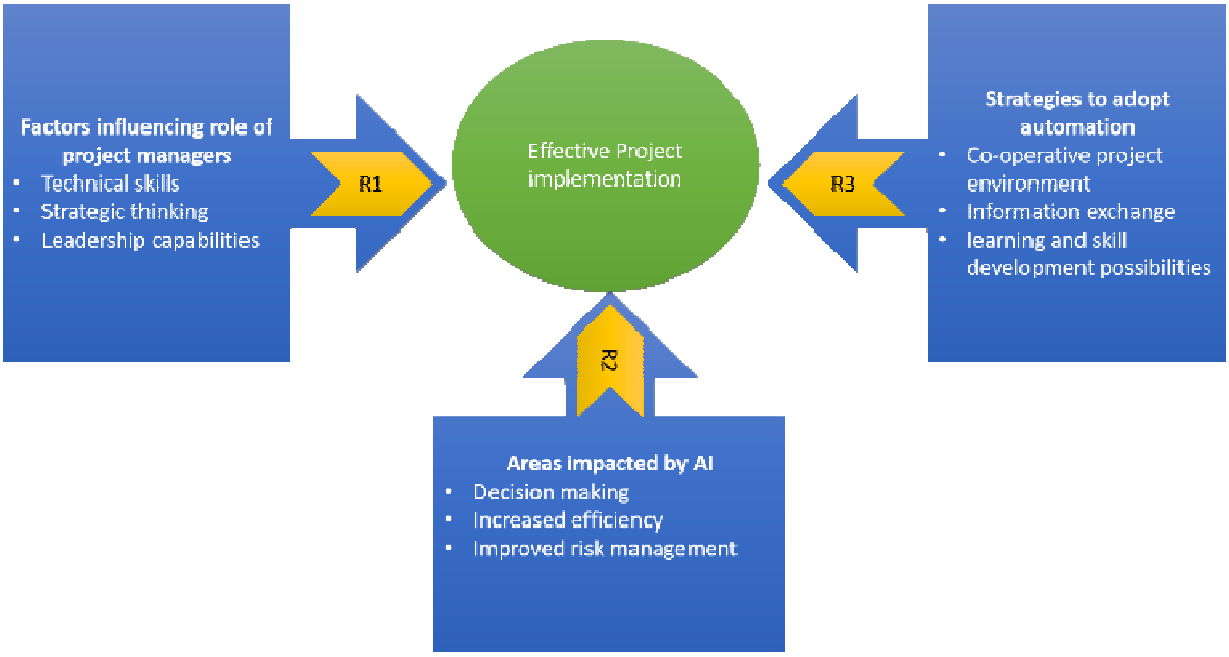

Fig. 1: Initial model of implementation of AI (own illustration).

Strategies for adopting automation in day-to-day work include applying various theoretical models such as UTAUT, TTF, OCT, HCI, SCT, and TAM to effectively incorporate AI in project management. These models emphasize the importance of AI systems matching job demands, navigating adoption barriers, providing intuitive interfaces, and considering social and attitudinal factors. By fostering a collaborative atmosphere and prioritizing learning, project managers can leverage these models for effective AI use, enhancing leadership, agility, and project success while acknowledging the critical need for human expertise and strategic foresight in technological adoption.

6 METHODOLOGY

The study utilized a qualitative research design, gathering both primary and secondary data sources to explore the impact of artificial intelligence (AI) on project management. Primary data was collected through interviews conducted in December 2023 and January 2024 via audio and video platforms such as Zoom and Microsoft Teams. Secondary data sources included books, journals, papers, and internal firm sources relevant to the study question.

The analysis employed both inductive and deductive qualitative approaches, as outlined by Philipp Mayring (2000). The inductive approach allowed for an open exploration of AI's impact on project management, uncovering new themes and insights from diverse data sources. Systematic coding identified significant trends regarding AI's role in automating tasks, enhancing decision-making, and improving risk management and teamwork.

Semi-structured interviews were the primary data collection method, blending predetermined questions with exploratory follow-ups to facilitate detailed discussions and enrich understanding of participants' experiences and perspectives. This approach supported an inductive approach to generate new insights and aimed to enrich debates around AI's integration in project management and guide workforce strategies. The combination of a case study design and qualitative analysis effectively revealed the complexities of participant experiences.

The research employed a purposive sampling strategy to gather a diverse dataset, supplemented by snowball sampling to expand the sample size. Interviews were conducted over a period from December 16, 2023, to January 23, 2024, totaling 10 sessions, offering both in-person and virtual options. Each session was audio-recorded and transcribed using speech-to-text software.

Interviews ranged from 40 to 85 minutes, aiming to explore perspectives of professionals across Europe and India. Data saturation determined the conclusion of interviews, indicating no new themes emerging. The qualitative analysis utilized coding and categorizing methods, with the MaxQda program managing data.

Direct quotes from participants were included in findings to ensure authenticity, with access to original transcripts provided in the appendix.

Ethical considerations included informed consent, confidentiality, anonymity, withdrawal options, and participant well-being. These guidelines aimed to uphold honesty, respect individuality, maintain privacy, and enhance study validity.

7 FINDINGS

7.1 Factors influencing the role of project managers in automation era

The responses outline diverse perspectives on the integration of artificial intelligence (AI) into project management, highlighting anticipated changes in job roles, dynamics, potential displacement of human workers, complementarity between human and AI intelligence, and the possibility of humans being at par with AI.

Anticipated Changes in Job Roles:

Respondents anticipate transformative changes in project management due to AI, including enhanced decision-making precision, task automation, improved risk management, and personalized learning opportunities.Challenges such as mindset shifts, resistance to change, and ethical considerations are emphasized, calling for a holistic approach encompassing education, organizational support, and ethical considerations.

Estimated Change in Dynamics:

Integration of AI is expected to lead to flatter hierarchies, foster collaborative work environments, and reshape work functionalities, with AI influencing areas such as task management, data analysis, and forecasting. Challenges include resistance to change, micro-management issues, and the importance of maintaining traditional organizational structures.

AI Leading to Displacement of Human Workers:

Perspectives vary on whether AI will displace human workers, with some emphasizing AI's role in redefining job roles rather than outright job loss. Challenges highlighted include mindset shifts, skill gaps, data quality, ethical considerations, and the need for effective human-AI collaboration.

Human Intelligence and Artificial Intelligence Complementing Each Other:

Respondents stress the importance of openness to new technologies, skill improvement, and a shift in mindset for project managers. There's recognition of the unique strengths of both human and AI intelligence, with an emphasis on their complementarity and the need for a balanced approach.

Humans at Par with AI:

Views differ on whether humans can be at par with AI, with emphasis on the development of soft skills and careful navigation of ethical considerations for effective AI integration. Challenges highlighted include resistance to change, organizational challenges, potential compromise of human attributes, and the need for continuous learning and adaptation.

Overall, the responses underscore the complexity of integrating AI into project management workflows, emphasizing the need for a holistic approach to address challenges and leverage the potential benefits of AI technologies effectively.

7.2 Areas of Project Management impacted by AI

The respondents collectively recognize the transformative potential of artificial intelligence (AI) across various areas of project management, highlighting its impact on decision-making processes, task automation, communication, collaboration, risk management, and resource allocation. They anticipate AI to streamline operations, enhance efficiency, and provide strategic insights. Key points from the discussions include:

Areas Impacted by AI:

AI is expected to influence various aspects of project management, including decision-making, communication, collaboration, task automation, risk management, performance monitoring, quality

management, and continuous improvement. Specific examples include AI's role in streamlining task allocation, scheduling, communication management, and resource optimization.

Tasks Benefitting from AI Integration:

Respondents identify tasks such as task scheduling, risk management, communication management, decision-making, trend analysis, resource allocation, and real-time monitoring as areas poised to benefit significantly from AI integration. They highlight AI's potential to automate routine tasks, provide insights for strategic decision-making, and improve overall project efficiency.

Leveraging AI for Decision-Making:

AI is seen as a valuable tool for enhancing decision-making processes by providing real-time insights, numerical comparisons, predictive analytics, and comprehensive data analysis. While AI can assist in decision-making by uncovering patterns and trends, respondents emphasize the importance of human judgment and oversight to ensure decisions consider all relevant factors.

Cautionary Notes and Perspectives:

Some respondents caution about the limitations of AI, particularly in handling complex communication tasks and human-centric aspects like creativity and emotional intelligence. They stress the need for a balanced approach, viewing AI as an advisor rather than a replacement for human judgment, and ensuring that AI-driven insights are carefully evaluated and overseen.

In summary, while AI is expected to bring significant benefits to project management by enhancing efficiency and providing valuable insights, it should be integrated thoughtfully, considering both its capabilities and limitations, and maintaining a balance between AI-driven automation and human decision-making.

7.3 Strategies to adopt automation in day to day work

The responses regarding effective strategies for adopting AI in project management emphasize the need for leadership support, strategic planning, team education, and a phased approach to implementation. Key points include:

Leadership and Cultural Shift:

Top-down leadership is crucial for fostering a learning environment and driving a cultural shift towards embracing AI in project management. Strategies should focus on raising awareness about AI, encouraging continuous learning, and creating a supportive environment for adopting new tools and workflows.

Strategic Planning and Adaptability:

Successful integration of AI requires strategic planning, adaptability, and careful task selection. Project managers need to keep pace with the rapid evolution of technology, ensure data reliability, and navigate ethical concerns associated with AI implementation.

Change Management and Training:

Change management training is essential to mitigate resistance to AI adoption and address micro-management issues. Practical skills development, including AI literacy, data literacy, technical proficiency in automation tools, and change management, is necessary for project personnel to effectively leverage AI.

Phased Implementation and Continuous Improvement:

A phased approach to AI integration, starting with small pilot projects and gradually scaling up, allows for learning from past experiences and continuous improvement. Training initiatives should provide practical exposure to real-life scenarios, emphasize communication skills, and include awareness of ethical considerations and cybersecurity best practices.

Overall, the responses underscore the importance of balancing technological advancements with human oversight and expertise, ensuring that AI complements rather than replaces human capabilities in project management.

Final Model Conceptualization

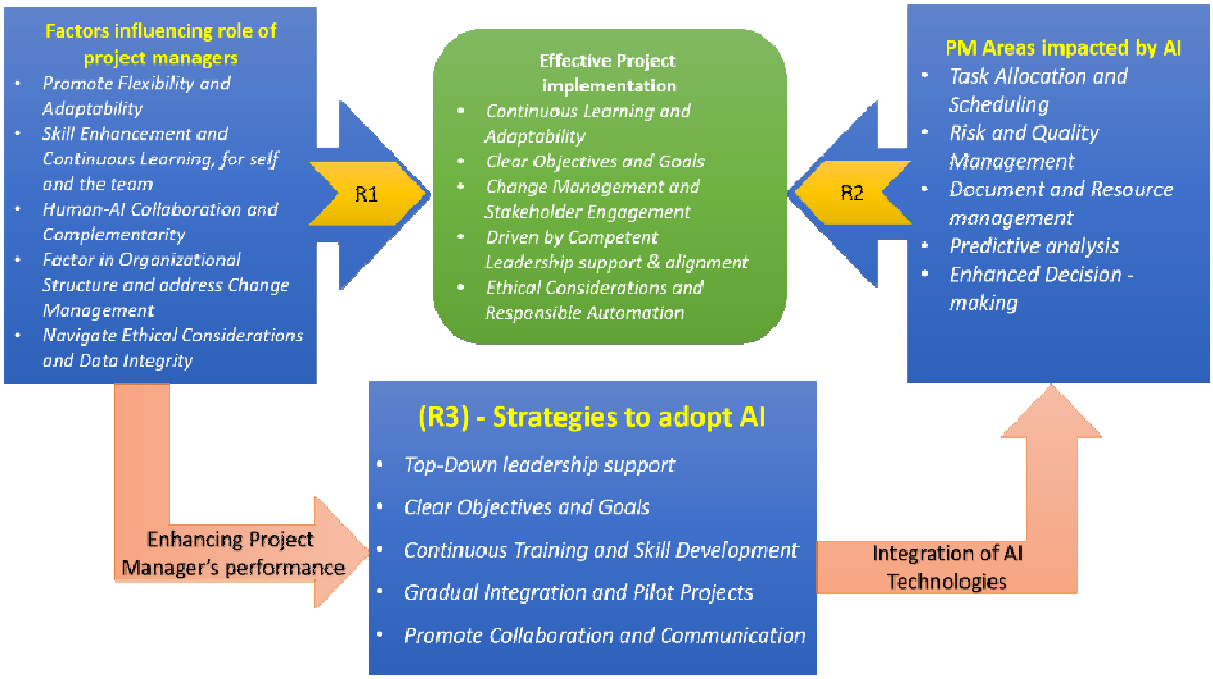

Fig. 2: Final model of implementation of AI in PM (own illustration).

The model outlines the process and considerations for integrating AI into project management to enhance project managers' performance and achieve effective project implementation. Key components of the model include:

Factors Influencing the Role of Project Managers:

Emphasizes the importance of project managers being adaptable, continuously improving their skills, effectively collaborating with AI, considering organizational structure, managing change, and upholding ethical standards and data integrity.

Strategies to Adopt AI:

Provides a roadmap for integrating AI into project management, highlighting the need for leadership support, clear goals, continuous learning, gradual AI integration through pilot projects, and fostering collaboration and communication.

PM Areas Impacted by AI:

Lists specific project management areas that AI will enhance, such as task allocation, risk and quality management, document and resource management, predictive analysis, and decision-making.

The model illustrates the flow and relationship between these elements, suggesting that enhancing project managers' performance with these factors and strategies will lead to successful integration of AI technologies, ultimately contributing to effective project implementation.

8 DISCUSSION

This study examines the impact of artificial intelligence (AI) on project management, including its effect on project managers' roles, vulnerable areas in project management, and strategies for AI integration.

Research Question 1:

Respondents (R1-R10) provide insights into the evolving role of project managers amidst AI integration.

Optimism about AI's potential:

- Emphasis on adaptability and continuous learning (R2, R6, R9).
- Importance of technical proficiency and ethical usage (Dacre & Kockum, 2022; Russell & Norvig, 2011).

Concerns raised:

Job displacement and micro-management issues (R1, R4, R7).

- Ethical implications and risks of AI technologies (Crawford et al., 2006; Hitt et al., 2017).
- Emphasis on balancing human intuition with technological assistance.

Research Question 2:

Recognition of AI's transformative potential:

Improvements in efficiency, decision-making, and team dynamics (R2, R7, R9).

Impact on project management areas:

- Planning, resource management, and communication (Hashfi & Raharjo, 2023; Lin et al., 2022).
- Advantages in scheduling, task allocation, and risk management (R1, R2).

Concerns about AI's limitations and job displacement (Geraldi et al., 2011; Li et al., 2021).

Research Question 3:

Strategies for AI integration:

- Top-down leadership (R1, R7; Venkatesh et al., 2003).
- Detailed roadmaps for gradual integration and upskilling (R2, R6; Davis, 1989).
- Practical tools and awareness programs (R3, R5).
- Systematic approach covering process assessment and continuous improvement (R9; Kwon & Zmud, 1987).

Emphasis on leadership support, clear objectives, upskilling, and ongoing evaluation for successful AI adoption.

9 CONCLUSION

This investigation explores the integration of automation and artificial intelligence (AI) into project management (PM), highlighting diverse stakeholder perceptions ranging from enthusiasm to concerns. It emphasizes the need for adaptability, lifelong learning, and strong leadership to navigate these transitions successfully. The analysis identifies key areas within PM, such as project planning and decision-making, poised to benefit from AI integration, despite its limitations in understanding human dynamics. Strategies for embedding automation into daily operations include leadership endorsement, skill development, incremental integration, and consistent review mechanisms. Overall, the research underscores the importance of informed strategies to fully embrace the transformative potential of automation and AI, propelling project management towards innovation and efficiency.

10 LIMITATIONS AND FUTURE RESEARCH

The study highlights significant insights into integrating artificial intelligence (AI) into project management (PM) but acknowledges methodological limitations. These include a small participant sample, a focus solely on project managers' perspectives, and reliance on self-reported interview data. Future research could address these limitations by expanding the sample size, incorporating diverse perspectives, and employing mixed-methods approaches for more robust data triangulation. Additionally, avenues for future exploration include investigating ethical considerations, conducting longitudinal studies on AI adoption's sustained impacts, and comparative studies across sectors and regions to understand contextual influences. Overcoming these limitations and pursuing these avenues can enhance our understanding of AI's role in PM and contribute to more effective and ethical project management practices.

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The Role of Public-Private Partnerships in Smart City Development: A South African Perspective

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1 ABSTRACT

Developing smart cities in South Africa is a transformative approach to address challenges such as rapid urbanisation, environmental sustainability, and economic development. This paper explores the role of Public-Private Partnerships (PPPs) in facilitating the development of smart cities, focusing on leveraging collaborative efforts between government entities and private sector stakeholders. The study uses a qualitative research approach, analysing case studies and policy frameworks, to highlight the potential of PPPs to mobilise resources, enhance technological capabilities, and foster innovation in smart city initiatives. The results emphasise the importance of innovation, public involvement, and strong PPP structures in advancing smart cities. The study concludes that effective governance, clear regulatory frameworks, and stakeholder engagement are critical factors in ensuring the success of PPPs in driving smart city development. The paper concludes with policy recommendations and strategic considerations for optimising the contributions of PPPs to South Africa's urban transformation agenda.

Keywords: PPP, Smart City Development, Urbanisation, Technical Advancements, South Africa

2 INTRODUCTION

The advent of the digital era has heralded a new paradigm in urban development, where cities are increasingly leveraging technology to enhance the quality of life, promote sustainable growth, and address complex urban challenges (Xihua and Goyal, 2022:190-195, Lynggaard and Skouby, 2016:1840, Lepekhin, et al., 2018:1029). Smart cities, characterised by integrating information and communication technologies (ICT) into urban infrastructure and services, have emerged as a strategic response to the demands of modern urbanisation (Lepekhin et al., 2018:1029). In South Africa, the pursuit of smart city development is seen as a pathway to technological advancement and a means to foster social inclusion, economic growth, and environmental sustainability (Cornelius, et al. , 2022:220-240). The primary aim of this study is to explore the role of Public-Private Partnerships (PPPs) in developing smart cities in South Africa. The objectives are to analyse the conceptual framework of PPPs, examine their dynamics in facilitating smart city development, identify the challenges and opportunities associated with their implementation, and provide policy recommendations for optimising their contributions to South Africa's urban transformation agenda.

The methodology of this study adopts a qualitative research approach, encompassing a comprehensive literature review, case study analysis, and semi-structured interviews with key stakeholders involved in smart city projects. The literature review provides a theoretical framework for understanding the dynamics of PPPs in smart city development. At the same time, the case studies offer insights into the practical application of PPPs in various urban settings. The semi-structured interviews with government officials, private sector representatives, and urban planners aim to gather firsthand perspectives on the role of PPPs in smart city initiatives, with thematic analysis used to identify recurring themes and patterns (Liu, et al. , 2021:138-156).

This research holds significance in multiple dimensions, contributing to the academic discourse on the intersection of PPPs and smart city development, providing practical insights for policymakers and urban planners, and offering lessons applicable to other emerging economies. The study is guided by research questions that seek to understand the conceptualisation of PPPs, the key factors influencing their success, the challenges faced in their implementation, and the policy implications for smart city development in South Africa. The findings are expected to inform strategies for sustainable urban development and enhance the efficacy of PPPs in transforming cities into smarter, more inclusive, and resilient urban environments.

The idea of cities, which involves using technology to improve infrastructure and services, is seen as a strategic response to the challenges of modern urbanisation. Private Partnerships (PPPs) play a role in implementing smart city projects by promoting collaboration between public and private sectors to bring together resources, expertise and innovation. However, there is a need to understand how these partnerships can be structured and managed effectively in dealing with governance issues, risk management, and stakeholders' involvement in smart city contexts.

To address this knowledge gap, it is suggested that future research should focus on creating frameworks that guide the planning, execution and evaluation of PPPs in smart city ventures (Liu, et al. , 2021:138-156). These frameworks should consider the needs of city projects, such as technology integration and cybersecurity. Moreover, there is a call for studies to explore approaches to engaging stakeholders and evaluating the economic impacts of PPP-led smart city initiatives, particularly in countries like South Africa. (Selim and ElGohary, 2020:317-333) highlight the critical role of stakeholders in the success of PPPs in smart infrastructure projects. Understanding and analysing stakeholders' roles can mitigate opposition and ensure effective project implementation, bridging the gap in stakeholder expectations (Selim and ElGohary, 2020:317-333).

By tackling these gaps and making recommendations through research efforts, we can deepen our understanding of how PPPs contribute to the development of cities and offer practical advice for policymakers and professionals involved in such projects.

This involves recording and studying real-life examples from locations to discover methods and insights gained in implementing Public-Private Partnerships for creating lasting changes in urban areas.

3 LITERATURE REVIEW

A literature review critically analyses and synthesises existing research on a specific topic, offering an overview of the current state of knowledge, identifying gaps, and highlighting key findings. It contextualises the research problem within the existing body of knowledge, thus shaping the research question and justifying the study's significance. Additionally, the literature review provides insights into the theoretical and conceptual frameworks used in previous studies, as well as the methodologies employed, demonstrating the researcher's familiarity with the literature and contributing to scholarly conversations on the topic (Paez, 2017:233-240, Turner, 2018:113-117, Stratton, 2019:347-349, Uru, et al. , 2021:141-149, El-Farargy, 2016:1-12).

3.1 PPP-based theoretical models within the smart cities

Cities worldwide are increasingly utilising public-private partnerships (PPPs) to tackle challenges in smart city development. (Liu, et al. , 2021:138-156) found that PPPs help overcome budgetary constraints and conflicting stakeholder interests. (Mustaffa Kamal Effendee, et al. , 2021:1066) highlighted the importance of sustainable business models for funding allocation. (Khanjanasthiti, et al. , 2021:10624) discussed the global shift towards smart city concepts to address urban complexities. Fernandes (2021) highlighted the need for innovative solutions and technologies in the face of new challenges like the COVID-19 pandemic.

(Liu, et al. , 2021:138-156) and colleagues, in 2020, put forward a plan to incorporate partnerships (PPPs) into the development of smart cities. They focus on five areas: integrating technologies, enhancing risk assessment, boosting citizen involvement in sharing data, urban sustainability and streamlining processes. (Israilidis, et al. , 2021:101989) and team in 2021 explore knowledge management viewpoints while (Osu and Navarra, 2022:129-136) in 2022 present a framework for data governance. (Khanjanasthiti, et al. , 2021:10624) in 2021, examine the evolution of the Gold Coast into a city, emphasising aspects such as technology advancements, innovation centres, human resources development, and governing frameworks. These sources offer a roadmap for harnessing PPPs in smart city initiatives.

The Hong Kong example demonstrates how Private Partnerships (PPPs) play a role, in smart city projects, emphasising the importance of evaluating costs and benefits beforehand. The city's substantial government investments in technology (Ye, et al. , 2021:31-39). Further studies have explored Hong Kongs impact on enhancing tourism, its Smart City Blueprint and its involvement in establishing data centres. This case study sheds light on the varied aspects of city growth while stressing the significance of thorough evaluation and strategic planning (Sun, et al. , 2022:763-778, Ye, et al. , 2021:31-39).

Scholars highlighted a different form of service, namely health services, which involved an analysis of the impact of PPPs on effectiveness, equality, and the national economy (Bhatt, et al. , 2021:106-109). This relationship was positive for the health sector in Turkey, as mentioned by (Erk, et al. , 2023:). All these studies in the cohort provide readers with clarity regarding the need for theoretical PPP models to develop smart cities in developing and underdeveloped countries (Erk, et al. , 2023:, Bhatt, et al. , 2021:106-109).

Developing cities relies on engaging residents and key stakeholders in gathering data to incorporate services and infrastructure efficiently. Platforms such as FixMyStreet and ClickFix play a role in improving infrastructure services. Collaboration, inclusivity, and solid institutional capacity are indispensable to fostering learning and revamping city infrastructure. The eco-efficiency of infrastructure is essential for rapidly growing cities. Involving the public in the planning and designing green infrastructure guarantees that community needs and preferences are considered. While integrating citizen feedback into policies poses a challenge, ensuring quality data and cybersecurity measures are in place is crucial, for successful execution. (Aljoufie and Tiwari, 2016:152-168, Ersoy, 2017:26-31)

Urban areas are being reshaped by cities that prioritise innovation and sustainability. They tackle housing and energy access issues while boosting city competitiveness and human resources (Nesti, 2019:289-304). Technology drives progress in environments (Scuotto, et al. , 2016:357-367). Smart cities should improve quality of life by utilising information and communication technologies, establishing governance models and fostering innovation. This approach goes beyond advancements to create public value, promote innovation, and ensure sustainability. Investing in infrastructure and knowledge sharing is crucial for involving residents in the planning and execution of city projects (Treude, 2021:769, Esposito, et al. , 2021:103329, Romanelli, 2020:2037-2052, Zeng, et al. , 2023:e0281862, Scuotto, et al. , 2016:357-367).

In areas it is essential for various groups such, as residents, businesses and academic institutions to work together to promote innovation and enhance the overall quality of life (Dezi, et al. , 2018:1247-1270). These joint efforts boost community involvement and tackle issues like transportation and eco-friendliness (Makieła, et al. , 2022:3516). The effectiveness of introducing technologies in cities dramatically depends on a blend of social and technological collaboration, ultimately leading to an improved quality of life for the residents (Radziszewska, 2022:957-945, Agbali, et al. , 2019:307-327, Giourka, et al. , 2019:4798).

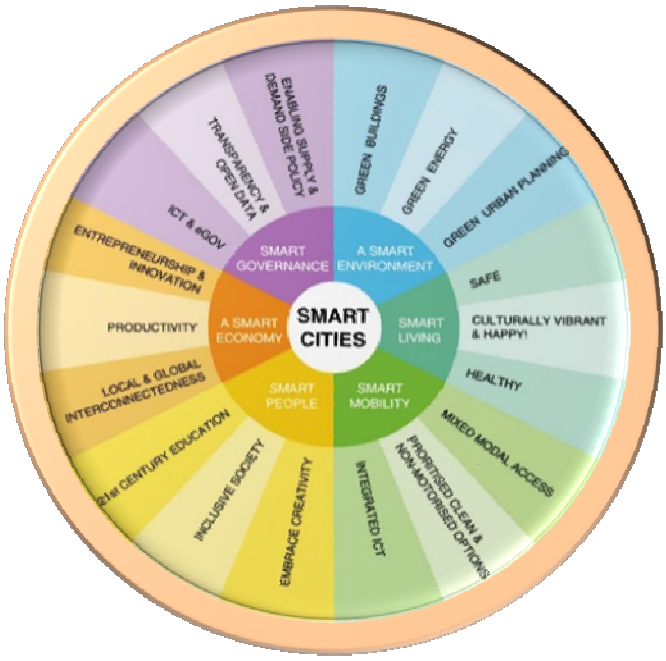

Figure 1 Examples of possible smart city elements and initiatives; Source: Giffinger et al., (2007)

To address these challenges and improve transparency and accountability in public-private partnerships, (Voorwinden, 2021:439-463) proposed a new approach that involved the production of recommendations and suggestions based on key performance indicators (KPIs), similar to the study by Awuah (2023) (Sheppard and Beck, 2022:843-861). These studies underscore the significance of engaging residents, addressing the challenges of integrating technologies in smart cities and promoting stakeholder collaboration

(Voorwinden, 2021:439-463). Given the complex nature of public-private cooperation in smart cities, it is essential to conduct extensive research and develop a framework that effectively addresses issues related to accountability and transparency (Liu, et al. , 2021:138-156, Khan, et al. , 2020:1507-1518, Voorwinden, 2021:439-463).

Smart cities combine various smart components that include, for instance, infrastructure elements. (Giffinger, et al., 2007:) identify the following areas: economy, people, governance, mobility, living and environment. Examples of possible smart initiatives that could be implemented in support of each of these areas are illustrated in Figure 1 below:

3.2 Smart City Projects Operating in South Africa

South Africa's President Ramaphosa introduced a plan for developing smart cities in 2019, focusing on sustainability, ICT infrastructure, and economic development (March and Naidoo, 2021:). This initiative aligns with the global trend towards smart city development, where Information and Communication Technology (ICT) plays a crucial role in enhancing urban sustainability and economic growth (Abed elhamed and Marzouk, 2019:78-95).

The smart city of Lanseria is under construction, aligning with the prior aim of using technology to improve living conditions. Implementing these strategies requires effective decision-making and efficient use of public-private partnerships (PPPs).

Only 22% of 167 cities worldwide have been leaders in developing smart cities. Ekurhuleni has emerged as an advanced city, making significant progress. The process of developing smart cities in South Africa has been complex, with challenges such as poverty, inequality, high implementation costs, security risks, regulatory deficiencies, and a shortage of required skills and labour (Enwereji and Uwizeyimana, 2022:93-109, Mokoena, et al. , 2019:1327-1332).

To address these challenges, the Department of Science and Innovation and the Academy of Science of South Africa recommend using PPPs to achieve inclusivity and innovation. However, there is a general lack of data maturity in South Africa, hindering smart governance and development initiatives (March and Naidoo, 2021).

Category and characteristics	**South African cities**
Technological Urban information management (internal and external) Information generation, capture and processing Data archiving, curation and storage Dissemination and discovery	A significant obstacle in South Africa is the absence of centralised and integrated data management systems across all municipal agencies, hindering the collection and reporting of data. Although these instances occasionally occur in many businesses, they are often utilised independently and in formats unique to each company, making them non-transferable. Furthermore, there is a notable absence of the necessary capacity and competence to do this task, with data champions being rare, if they exist. The eThekwini Municipality has just designated a Chief Digitisation Officer.
Methodological Data preparation: information retrieval and extraction, data linkage/information integration, data cleaning, anonymisation, quality assessment and credibility Urban analysis: methods for data-rich urban modelling and data-driven modelling; ascertaining uncertainty, biases, and error propagation	The specific delineation and prioritisation of IT soft and hard infrastructure, systems, and data strategies are lacking within and between departments. Urban areas suffer from a shortage of skilled professionals, such as statisticians and personnel, who can assess the trustworthiness and accuracy of data. Inaccurate and inconsistent data arises from several reporting platforms for many city agencies. Municipalities employ varied methodologies for data gathering, leading to inconsistent coverage across different data indicators.
Theoretical Understanding metrics, definitions, concepts, and changing ideologies and methods to understand "urban" Evaluating the soundness of methodologies and boundaries of knowledge Exploring the relationship between future cities, sustainability, and social justice.	South African cities lack a unified theoretical framework. The absence of information on the data gathered from various departments and the specific metrics employed by each agency necessitates acquiring data from private data providers, albeit at a financial expense.

Table 1 Key data challenges for cities. Source: Thakuriah (2017)

(Sanni and Hashim, 2014:133-138) emphasise the significance of public-private partnerships (PPPs) in South Africa's development of smart cities, drawing from successful PPP implementations is Singapore and South Korea (Kim, S. and Choi, 2023:142-155). They highlight the role of PPPs in mobilising funds and fostering innovation.

3.3 Examples of PPPs in South Africa

Public-Private Partnerships (PPPs) have been instrumental in advancing South Africa's infrastructure across various sectors. In healthcare, PPPs have facilitated the development of hospitals, ensuring efficient management and quality services. The transport and roads sector has improved through PPPs in road construction, maintenance, and toll management, enhancing connectivity and reducing congestion. The tourism industry benefits from PPPs in the development of attractions and accommodations, promoting growth and sustainability (Suryan, et al. , 2020:15-23, Seeletse, 2016:19, Nkhoma and Agbenyegah, 2021:799-817, Sinkala, et al. , 2022:152-183).

In addition to healthcare and transport, PPPs are utilised to construct and manage office spaces for government entities, optimising costs and efficiency. Equity partnerships in infrastructure projects foster shared investment, risks, and rewards, contributing to sustainable development. Facilities management projects extend the role of PPPs beyond construction, with private partners handling maintenance and operational tasks, enabling the public sector to focus on service delivery (Hellowell, 2019:e001217, Osei-Kyei, et al. , 2017:2092-2112, Kim, K., et al. , 2021:3311).

Notable PPP projects in South Africa include the Gautrain Rapid Rail Link, connecting critical urban areas, and the Nelson Mandela Bay Stadium, a multipurpose venue developed for the 2010 FIFA World Cup (Worku, 2020:259-268). The Bloemfontein Courthouse and the Lesotho Highlands Water Project highlight PPPs in judicial infrastructure and cross-border water supply, respectively (Worku, 2020:259-268). The expansion of the Durban Container Terminal and the development of the Cape Town International Convention Centre demonstrate the impact of PPPs on port efficiency and international convention hosting (Worku, 2020:259-268). These examples underscore PPPs' diverse applications and benefits in South Africa's development landscape.

4 METHODOLOGY

The researcher in question employed an interpretive research philosophy in conjunction with a unique descriptive content-analysis-based design as the primary research design for the study (Goel, 2023:3858-3875). This approach is commonly used in social science research (Malik and Gupta, 2022:). Interpretive research philosophy is known for its emphasis on understanding social reality through philosophical and methodological means (Botlhale, 2022:115-137). It assists in exploring the reality of the subjects involved in the research by explaining their intentions and actions (Zehra, 2016:). The study also adopted the inductive and qualitative case study research methods, aiming to extend theoretical insights into the information technology implementation literature (Utulu and Ngwenyama, 2021:1322-1340).

For data collection, the researcher relied on secondary reliable sources such as journals and case studies obtained from the Internet, which served as the primary methodological approach for the paper. This methodological choice aligns with interpretive analysis to clarify descriptive analysis through theory and previous research selected after performing the descriptive analysis (Pham, 2022:261-273).

Furthermore, the utilisation of interpretive phenomenological research methods was highlighted in the references. Researchers have claimed to use interpretive phenomenological methods in social science research, emphasising the need for a non-biased attitude by bracketing any preconceived beliefs (Singsuriya, 2015:348-358). Additionally, modifications of Ricoeur's hermeneutic phenomenology have been developed by nursing researchers, showcasing the evolution and sharing of interpretive methods within the research community.

In conclusion, integrating interpretive philosophy with a descriptive content-analysis-based design and reliance on secondary sources for data collection reflects a comprehensive and systematic approach to conducting the study, aligning with established practices in social science research.

5 RESULTS

Public-Private Partnerships (PPPs) are essential in developing smart cities in South Africa, addressing challenges and achieving innovative objectives. Critical themes for successful smart city projects include integrating technologies, addressing concerns, engaging residents, sharing data, and streamlining processes. Research on Hong Kong and Turkey highlights the importance of evaluating costs and benefits and the positive correlation between PPPs and factors like economy, equality, and effectiveness.

Research on smart city initiatives emphasises the need for collaboration among diverse stakeholders, such as citizens, industries, and research centres. The South African President's vision for developing smart cities prioritises sustainability, economic development, and ICT infrastructure to improve the quality of life. Collaboration with stakeholders is essential for success.

However, challenges such as lack of skills, regulatory uncertainty, security risks, and high implementation costs necessitate using PPPs to mitigate these barriers and achieve innovation. Innovative approaches to utilising PPP models, such as integrating blockchain and artificial intelligence, can enhance transparency and accountability. Citizens' active participation in decision-making processes is crucial for the success of smart city projects. Robust PPP frameworks are essential for achieving the development and growth of smart cities.

6 DISCUSSION

The present study examines the role of public-private partnerships (PPPs) in the critical development of smart cities in South Africa. Investigating theoretical models within smart city initiatives highlights the importance of cooperation between public and private entities. The study identifies PPP aspects, such as technology integration, risk profiling, and resident engagement, as essential in laying the groundwork for stakeholder involvement.

The research case studies and national development records illustrate the significance of PPPs in addressing challenges and achieving efficient smart city development, from infrastructure projects to hospital services. Stakeholders are advised to employ PPP themes to design a framework that promotes innovation, sustainability, and inclusivity in smart city development projects. Local governments or rule-makers can refer to the successes and limitations identified through the researcher's literary analysis.

There is a pressing need to adopt an approach that can effectively address these challenges. Future studies are recommended to explore regulatory bodies' concerns, investigate innovative technologies, and refine theoretical models to enhance smart city strategies. Adopting a citizen-centric approach can be effective in achieving sustainability and technological advancement. The researcher's recommendations can help mitigate concerns and focus on opportunities that can leverage PPPs for efficient smart city development in South Africa.

7 CONCLUSION

This paper aimed to provide insights regarding the role of PPP from a South African perspective. There is rapid urbanisation in South Africa, just like in many other parts of the world. These have created several challenges, as a result, smart cities have been developed to address these concerns, particularly in South Africa, where they aim to utilise smart technology to address the problems of municipalities.

Acknowledging that these enhancements come with a high price tag is essential. Therefore, private companies should allocate their resources towards improving public urban infrastructure, which lacks effectiveness and sufficient public funding. Several writers have highlighted the significance of utilising public-private partnerships (PPPs) in advancing smart cities in South Africa.

They have drawn on previous experiences and lessons acquired from the successful implementation of PPPs in countries like the UK, Australia, Singapore, and India. PPPs have been strongly emphasised in South Africa to mobilise funds and foster innovation. Several smart city initiatives have been carried out in South African cities, and all of these experiences underscore the significance of PPPs in overcoming existing challenges and developing smart cities.

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The Use of Situated Visualized Data to Nudge Visitor's Paths: a Case Study at the Detmold Design Week 2023

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1 ABSTRACT

In light of the rising importance of data transparency and open data guidelines (e.g. OGP Local[1]), Open Data Portals became standard in Smart City strategies (Van Oosterhout et al. 2020). While it is clear that these tools can serve as a valuable way for internal administration processes, at the same time it is critical that data is not only openly available following standard formats limited to computer-readability but above all also largely understandable for average citizens. For this reason, it is researched how open data can not only be made available but also visualized in an accessible way to all citizens. Moreover, the aim is to simultaneously boost private behavior changes which are inevitable to achieve locally-set goals in sustainability (Barr et al. 2011, TWI 2050 2018). To do so, we draw on the principle of nudging. Following the tradition of behavioral economics, nudging is defined as a positive intervention that induces a voluntary change in behavior without resulting in external (negative) consequences (Thaler & Sunstein 2008) and thus contrasting interventions like commands or bans because freedom of choice is maintained (Mongin & Cozic 2020, Ranchordás 2020).

This paper discusses an installation that explored the potential of combining nudging and situated visualization to improve data transparency and support individual decision-making in urban public spaces. During the Detmold Design Week 2023, an event showcasing creative works in various locations, the visitor numbers at nine locations were captured using computer vision. Visitors then received on-site suggestions in real-time for the next place to visit based on the occupancy. A survey was conducted to evaluate visitors' willingness to follow these data-informed suggestions. Findings highlight the importance of balancing between simplicity, relevance and privacy in data visualization. The results of the field test provide the foundation for the installation of interactive interfaces in Detmold's public spaces in the next years, in particular for communicating smart city topics focusing on mobility and urban climate protection.

Keywords: Situated Visualisation, Nudging, Planning, Computer Vision, Human-computer interaction

2 INTRODUCTION

In urban development policy, getting all stakeholders to behave in accordance with goals that are widely accepted in the population e.g. in climate protection presents a significant obstacle (Klementschitz et al. 2020). Opposed to commands or bans, the principle of nudging consists in inducing a voluntary change in behavior while maintaining freedom of choice (Thaler & Sunstein 2008, Mongin & Cozic 2020, Ranchordás 2020). Nudging is widely used to incentivize more sustainable choices in various fields like mobility, traffic safety, management of public spaces, energy consumption (Bandsma et al. 2021, Ranchordás 2020) etc. Behavior Change Techniques are mainly based on the assumption that public policies cannot rely on rational responses by individuals if the decisions contradict their inner beliefs, needs etc. (Loidl et al. 2023, Mongin & Cozic 2020, Thaler & Sunstein 2008). Klementschitz and colleagues describe four pathways for nudging: "1. simplification and framing of information, 2. changes to the physical environment, 3. changes to the default policy and 4. the use of social norms" (Klementschitz et al. 2020). With the shift to a digital society, improved affordability of sensors and therefore the constant collection and analysis of data, the application area is expanding to include digital nudging (Loidl et al. 2023, Weinmann et al. 2016).

Current debates discuss data protection challenges and ethical guidelines for an approach to nudging that addresses the potential paternalistic tendencies in influencing people's behavior (Huber et al. 2023, Klieber at al. 2020, Mongin & Cozic 2020, Ranchordás 2020, Santos Silva 2022). Research has also explored the

[1] www.opengovpartnership.org/ogp-local/

implementation of nudging in contexts of circular economy, e.g. in the project Antwerp Circular South which combined sending app-messages with weekly reports, group challenges, competitions, rewards and emotion-provoking images regarding energy use in peak hours, garbage reduction and water consumption and sensors to control the results (Hofman & Van de Mosselaer 2021, Smets & Lievens 2018). Others have utilized the concept to nudge travelers to use socially favorable routes by trialing modified design of cartographic symbolization based on scenarios for traffic and air quality (Fuest et al. 2023).

Although these studies show the application of nudging in Smart City contexts, it is apparent that most solutions rely on smartphone-applications as a tool for visualization. Online Open Data Portals are also standard in Smart City strategies (Van Oosterhout et al. 2020) when conforming to the current data transparency and open data guidelines (e.g. OGP Local). According to these guidelines, data must be openly available in computer-readable formats, but the question of how to visualize the data in a human-readable format for the average citizen is left to researchers (Ansari et al. 2022). Moreover, when available online, the data reaches only those citizens that actively look for it. When trying to nudge citizens in the direction of more sustainable choices, data can be used to inform and back-up such choices, if visualized in an understandable way and reachable where the citizen can see it passively. Insights into other types of visualization for nudging are limited and we aim to identify how on-site display of information and nudges can be combined in the later-presented case study and therefore contribute to this incomplete body of research.

Previous research in human-computer interaction (HCI) has already explored the concept of so-called situated visualization. According to White & Feiner, this term refers to "a visualization that is related to and displayed in its environment" (White & Feiner 2009). Other authors expand the definition by taking into account that the place of visualization must have relevance for people (Bressa et al. 2022). Situatedness incorporates the contextual, local and social environment (Huber et al. 2023). Projects using situated visualizations use a variety of technologies, data sets, methods and visualization styles (e.g. artistic, physical) (Bressa et al. 2022). While situated visualizations are at their core displays of information (e.g. Vande Moere & Hill 2012, De Macêdo Morais et al. 2019, Wiethoff & Hoggenmueller 2017), related projects often provide additional functionalities such as voting (Behrens et al. 2014, Claes et al. 2018, Koeman et al. 2014, Steinberger et al. 2014, Valkanova et al. 2014) or facilitating user-created content (Claes et al. 2018, Fischer & Hornecker 2012). Situated visualizations are considered to be highly relevant in dealing with digital information, as they provide users of urban (digital) services with a detailed overview and, as a result, enable better decisions (Martins et al. 2023).

Several projects have meaningfully deployed the concept of situated visualization. Nuage Vert in Helsinki, Finland, visualized the energy consumption of the inhabitants through a low-energy laser light which lit up the projection surface of a cloud caused by emissions of an electricity plant chimney and automatically adjusted according to the consumption rate (Vande Moere & Hill 2012). "Data on Site" combined several wirelessly networked e-ink displays installed on street-facing windows, which visualized data-sets and diagrams regarding topics like air quality or local shopping habits (Claes et al. 2018). Our research is based on the current leading discussion in situated visualizations, namely, achieving high interaction rates with the physical installations and attaining high effectiveness in communicating information, while also ensuring inclusiveness for the majority of inhabitants (Caldwell et al. 2016, Letondal et al. 2023, Steinberger et al. 2014, Wiethoff & Hoggenmueller 2017).

In the installation "Where to go next?", we tested the use of situated data visualization in public spaces to nudge users' decision-making based on the number of visitors in different event locations. In this case study we conducted an experiment to evaluate citizens' willingness to follow computer-generated data-based recommendations presented directly on site. In presenting this field test, we wish to bring attention to the opportunity to connect nudging with situated visualization to, on the one hand, improve transparency for citizens regarding data collection in Smart Cities and on the other hand encouraging favorable behavior through interaction and information. One main task was to explore how data can be visualized in such a way that the associated relevance can also be communicated through the design. To do so we build on the theoretical and applicatory insights from the earlier presented case study examples.

3 CASE STUDY SETTING

The installation took place during the Detmold Design Week (DDW) 2023 (detmolderdesignwoche.de), an event that occupies vacant stores and abandoned industrial buildings in the city for a week to showcase independent designers' and artists' works. The first event in 2022 had more than 1500 visitors and was received very positively by the population. With 30 different exhibition locations, the second year week presented a good opportunity to test the concept of a decentralized data-supported nudging system. The number of visitors at selected exhibition sites was collected and visualized in real-time on-site (see Figure 1). The nudging was tested in the form of suggestions for the next location to visit based on the occupancy of surrounding locations. In order to be able to give suggestions on which location to visit next, the visitors were counted to determine the occupancy of each location, using a computer vision algorithm.

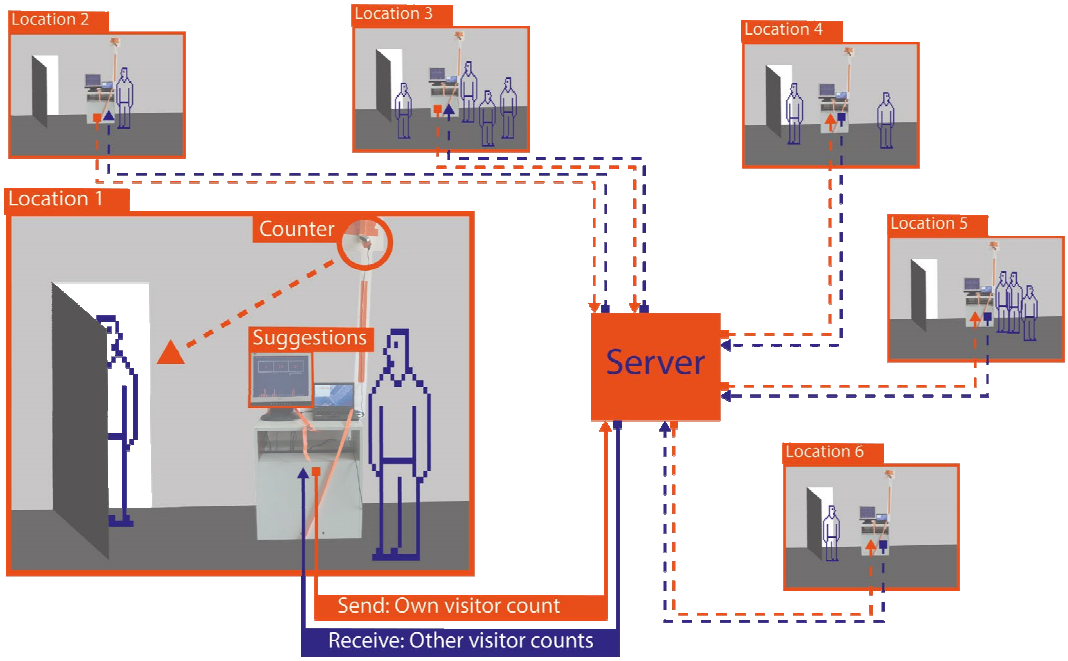

Figure 1: General setup of the case study in different locations with data exchange through server.

4 CASE STUDY DESIGN

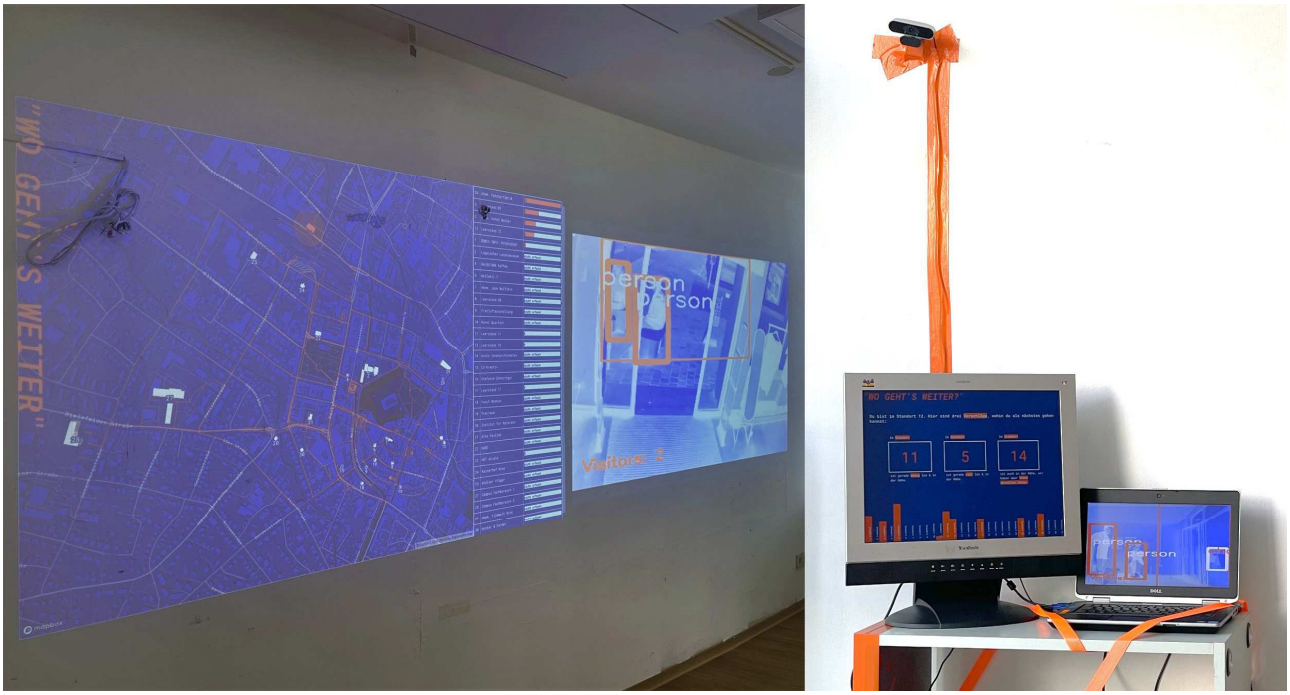

Figure 2: Projections at the DDW info point and data collection and on-site visualization setup.

The DDW's info point was chosen as the central point for the installation, where all information was visualized and visitors could find a team member for questions at all times. It was equipped with two projections (see Figure 2), one showing the map of all locations (described in 3.2.1), the other streaming the video of the people counter (described in 3.2.2). The projections were run by a standard laptop (12 years old/intel i5 processor/4gb RAM, no dedicated GPU), which also hosted the computer vision algorithm (described in 3.1) using the connected webcam (FHD, 120-degree wide angle).

Besides the central information point, 8 other locations were selected for data collection and on-site visualization. In each entrance area, the same type of laptop and webcam as described above and an additional second screen were installed (see Figure 2). The laptop screen showed the live stream (as described in 3.2.2), on the second screen suggestions where to go next (as described in 3.2.3) were visualized.

In all locations, posters explained the idea of the installation and the technology behind it, especially focusing on privacy concerns and transparency in the whole data collection process. Furthermore, a QR code directed the visitors to the survey (described in 3.3) and an Instagram account, where more information was available. In the following, the setup is explained in detail, divided in the data collection process, the data visualization and the survey structure.

4.1 Data collection: computer vision algorithm

The fast development of machine learning and deep learning helped bringing many recent advances in the field of computer vision (Cob-Parro et al. 2021). Most relevant is the introduction of the algorithms R-CNN, fast R-CNN, faster R-CNN, SSD (single shot detection) and YOLO (you only look once) (ibid.). For this case study, a SSD algorithm was used for object detection.

Unlike other methods, which analyze the video in a server or cloud solution, shifting it towards the location (so called edge computing) reduces network traffic (Herelia & Barros-Gavilanes 2019) and helps reducing privacy concerns. Since computational power at each location was limited though, the algorithm had to be as light as possible. It is based on Adrian Rosebrock's OpenCV People Counter (Rosebrock 2021) but was modified as explained in the following. First the video is analyzed locally in real-time to detect people and other objects. After detection, the algorithm is able to track the object through the image.

For object detection, mobilenet-ssd, a Single-Shot multibox Detection (SSD) network was used, as presented by Liu et al. In 2016 (Liu et al. 2016). The network uses the deep learning framework Caffe (Convolutional Architecture for Fast Feature Embedding) to store and represent trained neural network models and is available on Github (https://github.com/chuanqi305/MobileNet-SSD) with pre-trained weights on Pascal VOC (Visual Object Class) 2007 and 2012, which is a widely used benchmark dataset in computer vision. It combines two editions of the dataset, namely VOC2007 and VOC2012, which were released as part of the Pascal VOC challenges. The available pre-trained network contains 20 different object classes, including common objects such as people, cars, animals, and household items. The mean average precision is mAP=0.727 (https://github.com/chuanqi305/MobileNet-SSD). In the case of this project, only objects identified as people are relevant. Every frame of the live video is sent through the SSD network, using Open CV's deep neural network module. Objects with the class people are further processed.

After successfully detecting the visitor, the dlib correlation tracker is activated in order to keep track of it, as done by Rosebrock (Rosebrock 2021). In his approach, the visitor is counted after crossing a predefined line (LOI: line of interest) as an entry or exit, depending on the direction. This is useful for an installation in a clear entry situation with one opening and a clear walking direction towards it through the given floorplan. In other approaches (Kowcika & Seshadri 2015) the number of people inside a certain area (ROI: region of interest) is counted. This can be done, if the camera is able to face the whole location and count all current visitors. In our case, it was needed to come up with a new approach, which is also based on a region, but where not only people inside the region are counted, but also the direction is relevant, meaning it makes a difference if the object appears first in the region and leaves it, or in the opposite direction (see Figure 3).

The door or opening is marked as polygon, and the counter is activated if an object left or entered this region. This approach brings benefits for locations, where it is not possible to use LOI, because of the given floorplan. For calculating the direction of the objects' movement, Rosebrock calculates the average of all its previous locations and the latest location, to create a vector (Rosebrock 2021). For this case, the first

location, where the object appeared, and the current location was taken into account instead, which showed better results in testing. Moreover, the code was modified in such a way, that also visitors that entered the polygon but then reentered the room, would be taken into account properly. Every 15 seconds, the current number of visitors is sent to the database using a request.

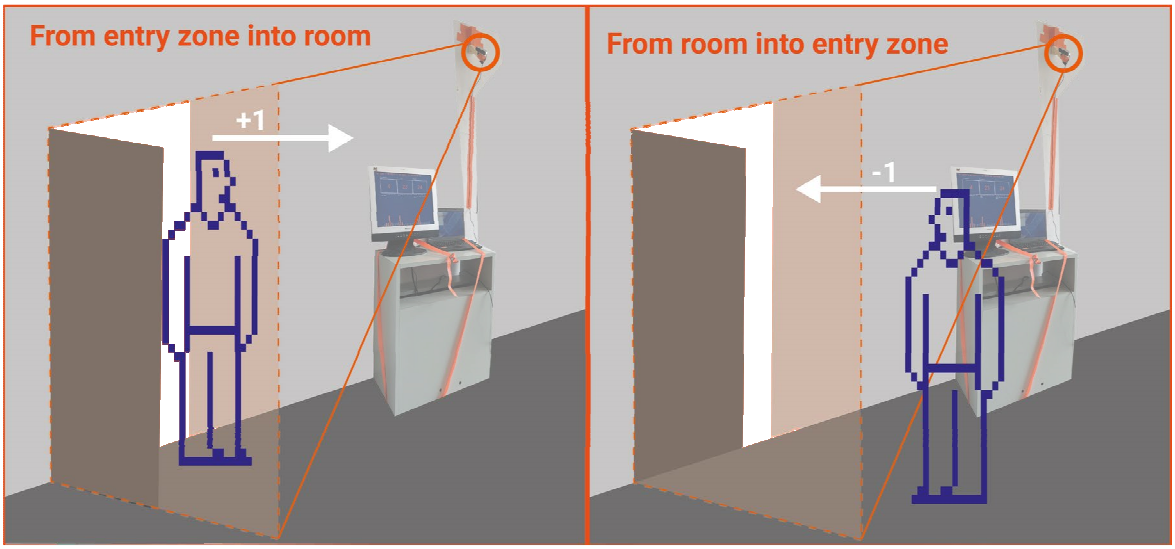

Figure 3: Region of interest (ROI) principle for counting algorithm.

4.2 Data visualization

The collected data was visualized in three different ways throughout the exhibition, described in detail below: map, camera view and suggestions.

4.2.1 Map

The map (see Figure 2) shows an overview of all the data being collected at all 9 monitored locations of the DDW. The larger the dot on the map, the more visitors were currently at that location. Despite not being tracked, the remaining 21 locations were marked with a white dot, so visitors would still be aware of them as options to visit. The list on the right side of the map was updated in real-time, with the most visited location always at the top. The orange network displayed showed the shortest routes between the 30 locations, where it was likely to encounter many DDW visitors. In the online interactive map, available on a tablet at location 1 and also shared on social media, the user could click on a location and see the number of people there, the time of the last update and the name and number of the location. Some visitors later informed us that they actually used the map at home to check which locations were more eventful. In the final days of the week spontaneous finissages were happening in some locations, which were not mentioned on the event's agenda and were being spontaneously shared on social media. The map could then assist the visitors to find these unscheduled events.

4.2.2 Camera view

Besides showing the resulting data, a main concept was also the visualization of the technological principles behind it, in this case the object detection via webcam. By doing so, the mistrust over cameras was supposed to be reduced and data transparency maximized, the understanding towards the technology enhanced and interaction engaged. In each location, the live stream was therefore visualized in real time. The detected objects were then marked as such and given a matching tag, e.g. person or cat, depending on the algorithm (see Figure 2). Using a real time filter from Open CV, the stream was modified into a more abstract picture, which made individuals almost unrecognizable, while still being identified as object.

4.2.3 Suggestion/Nudging Algorithm

For suggestions, all locations within a radius of 300 m were considered. Visitors were given a suggestion for the location with the fewest visitors, the one with the most, and a randomly selected location where we did not conduct measurements. The goal of the nudging was not to favor some locations over others, but instead to motivate the visitors to always move to a next close location, instead of finishing their visit at the present one or moving to a further location while missing others that were close by. For this reason, the locations

with no data were also included as an option, while the other two options backed with data were given to test if the data itself played a role in the decision-making. All options were visualized on the second screen in each location (see Figure 2), together with an abstract overview on visitor numbers of all locations.

4.3 Survey

Visitors were invited at the locations to scan a QR Code and take part in an online survey to evaluate their willingness to accept data-informed suggestions in public places. The survey contained 11 questions (7 close-ended and 4 open-ended) and explored the following three themes: 1. willingness to follow data-informed suggestions, 2. feelings and trust towards the technology and 3. willingness to share their own data. It was advertised through QR codes in the exhibition and also online on social media (Instagram). Visitors were also actively recruited in person by our team to take part in the survey. Since the participation in the survey (n=38) was too low to give representative results, it is only possible to get first insights on the topic and also test the survey for comprehensibility. With this in mind, the results are listed in the following.

With the first question, which asked if the suggestions shown in the locations impacted their way through the event, 11 users had to be filtered out, since they were not aware of any suggestions. From the remaining 19 users, ten reported that yes, the recommendations impacted their way through the exhibition and nine responded that no, they did not have an impact.

When asked why the recommendations impacted their way through the event, four respondents answered that the information helped them to orient themselves, but sometimes they didn't follow them anyway. Another four answered that they wanted to go where less or more people were, and the suggestions helped them with that. And two respondents liked that they didn't have to think where to go next.

Among those who were not impacted by the recommendations, four answered that they would rather follow their own way and four thought that the recommendations were not relevant for them. We also asked if the visitors could imagine using publicly visualized data, like it was done with the visitor numbers, for daily decisions. One visitor responded in the free text field that it would depend on each situation, four visitors responded no and 14 responded yes.

Besides whether or not the visitors were impacted by the recommendations, we were also interested in exploring how they felt about their data being collected and used in this manner. When asked how the presence of the camera made them feel, 13 respondents reported being interested, three were indifferent and another three felt insecure. From those respondents that felt indifferent as well as from those who felt insecure, two out of three responded that their feeling towards the camera changed for the better after understanding how the data is anonymously processed and not saved.

5 DISCUSSION

The survey showed that visitors principally react to nudging-based situated visualizations and also that the questionnaire was suitably designed to provide results for the targeted topics. In general, the importance and meaningfulness of the survey is relatively low though, since only a small percentage of visitors participated. A stronger presence of interviewers at the locations and visual promotion of the survey through posters etc. could increase the number of respondents in the future. The implications and questions deriving from the survey, but also conversations and observations during the test, are summarized in the following.

Does transparent data collection and processes motivate participants? The survey hinted on that by focusing on transparency during data collection and visualization, people can be motivated to participate. This was also reflected in several conversations with visitors. Based on observations, the transparent visualization of the data collection process helped to motivate people to come closer, read the recommendations and get informed about the study.

Are people open to follow suggestions informed by situated data visualization? The received results are not representative for giving a conclusive answer to this. Out of 19 visitors, 14 answered that they could imagine using situated data visualizations for daily decision making. 10 out of 19 answered that the suggestions had an impact on their way through the exhibition. In conversations, visitors acknowledged the relevance of this type of interfaces for the urban space and showed willingness to use them and contribute with data.

How does the data have to be visualized and contextualized? Three visitors stated that they would also like to have a map showing them where to go next. The researchers' focus on keeping the data visualization simple ended up leaving out an important piece of information that would have been relevant for the visitors and eased their experience following the suggestions. For the maps, the work of Fuest et al. 2023 could be valuable since they focused on ways of visualizing maps and directing people. Some visitors were not even aware of the suggestions, indicating that the visualization and/or the posters explaining the experiment failed partially in transmitting the message clearly to all. This shows that a balance between choosing the right information to be shown and keeping it direct, simple and clear is necessary.

How can engagement be generated? Based on observations and conversations with visitors the playful visualization of the live stream (see Figure 2) helped in getting visitors engaged. Some would recognize themselves and move around the camera picture to see if the classification and tracking would keep up with their movements. Some would try to change their classification by changing posture or raising their arms, imitating a dog or a cat. Through this, awareness for the field study was created and also conversations about it started. In the further development, tangible elements are planned as well in order to attract people and engage them, as done by Claes & Vande Moere 2018. According to them, "especially in the context of the visualization of data in the public realm, offering tangible interaction modalities might actively attract and engage passers-by, and lead to increased information discovery" (ibid.).

Technical challenges. While not being the focus of the field test, the algorithm for counting visitors was not as accurate during the week as during testing before. This was mainly due to the different entry situations in each location, with some better suited and some less suited, as well as due to the lack of computational power. Another challenge was ensuring a steady internet connection for all locations. Public Wi-Fi networks turned out to be too unstable for the study, while individual sim cards for each location were too expensive. In the future, a city-wide LoRaWAN network would be helpful for the data exchange.

6 CONCLUSION

In this study, we explored the use of situated visualization in nudging users' decision-making. Using the visitor count of several locations at the DDW as example, our focus was mainly on running a first test on the general acceptance of situated visualizations and the visitors' willingness to use such interfaces. The installation during the Detmold Design Week showed great potential for nudging through data visualization, even though problems and challenges appeared during the execution, which we identified through the survey, observations and conversations. In conclusion, a good balance between choosing the right amount of information to be shown while still keeping it as simple as possible and also balancing between privacy concerns and personal relevance has to be found. The interactive and playful character of the installation proved to be very helpful for engagement.

As part of an ongoing research project with the city of Detmold, the concept of a situated visualization based nudging system is going to be further developed with the goal of integrating it in the urban public space (streets, squares, etc.). This first test gave valuable insights, even though the survey answers were not representative for giving a conclusive answer yet. With more tests using the same survey, this will be improved. In an iterative research through design process, the next steps are to develop suiting interfaces which incorporate tangible elements for enhanced engagement as done by Claes & Vande Moere in 2015 and Claes et al. in 2018. A connection to the future open data platform of the city is planned to be implemented, thus making it a universal tool for visualizing a variety of urban datasets.

7 ACKNOWLEDGEMENTS

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Transformation ehemaliger Arbeiterinnen- und Arbeitersiedlungen in Niederösterreich

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1 ABSTRACT

Der gemeinnützige Wohnbau stellt in Österreich eine wesentliche Säule für die Schaffung und Sicherung sozialen und leistbaren Wohnraums dar. Viele der heute rund 185 gemeinnützigen Wohnbauvereinigungen sind in der Tradition entstanden, Arbeiterinnen und Arbeiter – rund um Fabriken und Arbeitsstätten – mit adäquatem Wohnraum zu versorgen. So sind nicht nur in den Landeshauptstädten, sondern auch in ländlichen Gemeinden, die durch Industrialisierung geprägt waren, insbesondere zwischen den 1920er und 1970er Jahren zahlreiche Arbeiterinnen- und Arbeitersiedlungen entstanden. Heute sind diese Siedlungsstrukturen vielfach erneuerungsbedürftig und stehen vor der Herausforderung, in Hinblick auf Wohnungsangebot und Wohnformen, aber auch in Hinblick auf Energieversorgung und Klimaresilienz an aktuelle Anforderungen angepasst zu werden. Die Relevanz dieses Themas zeigt sich auch in Zahlen: Der Bestand gemeinnütziger Wohnungsunternehmen umfasst mit 971.050 Wohnungen rund 20% des Wohnungsbestands in Österreich (Statistik Austria 2022), ca. 489.020 Wohneinheiten bzw. rund 10% wurden bis 1980 errichtet (GBV 2021).

Keywords: Smart City, Klimaresilienz, Partizipation, Revitalisierung, Arbeiterinnen- und Arbeitersiedlung

2 EINLEITUNG

2.1 Begleitung von zwei Smart-Cities-Projekten in Niederösterreich

Die Caritas Stadtteilarbeit leitet aktuell zwei Smart-Cities-Projekte, die vom Klima- und Energiefonds gefördert werden und sich mit der Weiterentwicklung ehemaliger Arbeiterinnen- und Arbeitersiedlungen in Niederösterreich befassen: „Transform Ternitz“ setzt sich mit der ehemaligen Stahlstadt Ternitz auseinander, welche seit den 1970er Jahren von einem starken Strukturwandel und Rückgang der lokalen Industrie geprägt ist, und entwickelt neue Strategien für die so genannte „Dreiersiedlung“. „Zukunft Siedlung“ ist in der Gemeinde Zwentendorf an der Donau angesiedelt und beschäftigt sich mit der Siedlung in Erpersdorf.

Der Bau beider Siedlungen erfolgte großteils in den 1940er Jahren. Heute weisen die – nach dem Leitbild der Gartenstadt errichteten – Siedlungsstrukturen einerseits hohe städtebauliche Qualitäten mit großzügigen Freiräumen und Hofsituationen auf, andererseits zeigen sie einen starken Erneuerungsbedarf mit Blick auf Bausubstanz, Klima- und Energiefragen. Gemeinsam mit den gemeinnützigen Wohnbauvereinigungen, in deren Eigentum und Verwaltung sich die Siedlungen befinden, sowie mit Fachplanerinnen und Fachplanern aus Architektur, Freiraumplanung, Energieplanung und Mobilität werden Konzepte für Umbau und Weiterentwicklung der Siedlungen entwickelt. Ziel der Projeke ist es einerseits, für die ehemaligen Arbeiterinnen- und Arbeitersiedlungen konkrete Umbaustrategien zu erarbeiten, prototypisch zu erproben und so in der Praxis aufzuzeigen, wie Revitalisierung – in sozialer, ökonomischer und ökologischer Hinsicht – möglich ist. Innovativer Baustein ist dabei auch die partizipative Herangehensweise: Bewohnerinnen und Bewohner – Ältere und Jüngere, Familien, teilweise Menschen mit geringen Einkommen und zunehmend auch mit Migrationsgeschichte – sowie Vertreterinnen und Vertreter der Gemeinde werden aktiv eingebunden, um neue Zukunftsvisionen und bedürfnisorientierte Lösungen zu kreieren. Andererseits zielen die Projekte auf Kompetenzentwicklung und Prozessinnovation ab, indem sie von entwickelten Handlungsansätzen lernen und diese auch für weitere Siedlungen nutzbar machen.

2.2 Ein vergleichender Blick auf die Weiterentwicklung der Siedlungen

Der folgende Beitrag nimmt eine vergleichende Betrachtung der beiden Projekte vor. Dabei werden zunächst die Transformationprozesse von ehemaligen Arbeiterinnen- und Arbeitersiedlungen anhand der zwei Beispiele erläutert. Anschließend werden die partizipative Prozessgestaltung und die dabei jeweils konkret angewendeten methodischen Instrumentarien näher beleuchtet. Auf Basis von Befragungen und

partizipativen Formaten werden Herausforderungen und Chancen in den beiden Siedlungen aus Sicht ihrer Bewohnerinnen und Bewohner skizziert. Abschließend werden unterschiedliche Handlungsstrategien, die daraus entstanden sind, aufgezeigt und zum aktuellen Forschungs- und Entwicklungsstand identifizierbare Lernerfahrungen herausgearbeitet. Mit dem Beitrag wird einerseits die Perspektive von Bewohnerinnen und Bewohnern in den Vordergrund gerückt, andererseits der vergleichende Blick auf zwei ähnlich und doch spezifisch gelagerte Smart-Cities-Projekte gelenkt.

3 ARBEITERINNEN- UND ARBEITERSIEDLUNGEN IN TRANSFORMATION

Ehemalige Arbeiterinnen- und Arbeitersiedlungen sind heute mit vielfältigen Veränderungen konfrontiert. In sozialer Hinsicht hat in den letzten Jahrzehnten ein struktureller und soziodemographischer Wandel stattgefunden, der auch mit veränderten Wohnbedürfnissen und Nachbarschaften einhergeht. In ökologischer Hinsicht stellt sich die Frage, wie statt häufig noch mit Einzelöfen beheizten Wohnräumen für ganze Siedlungen nachhaltigere Energiesysteme gefunden und Maßnahmen in Richtung Klimaneutralität gesetzt werden können. In ökonomischer Hinsicht gilt es, die Investitionen in Modernisierung für die Wohnbauvereinigungen finanzierbar und gleichzeitig für die Bewohnerinnen und Bewohner leistbar zu gestalten. Ein Blick nach Ternitz und Zwentendorf zeigt dabei sowohl ähnliche Phänomene als auch unterschiedliche Dynamiken.

3.1 Industriell geprägte Geschichte und Strukturwandel

Beide betrachteten Gemeinden sind in ihrer Entwicklung durch industrielle Entwicklung geprägt. In Ternitz haben sich bereits im 19. Jahrhundert Industriebetriebe angesiedelt und im 20. Jahrhundert wurde insbesondere die Stahlindustrie rund um die Schöller Bleckmann Werke bzw. die Verstaatlichte Industrie nach dem Zweiten Weltkrieg zum Motor für ein starkes Wachstum der Gemeinde. Im Rahmen der so genannten „Gastarbeitsmigration“ kamen dabei auch zahlreiche Arbeitskräfte aus dem Ausland, insbesondere aus der Türkei, nach Ternitz. Seit den 1970er Jahren erfährt Ternitz allerdings einen Strukturwandel, Teile der lokalen Industriebetriebe wurden geschlossen und die Anzahl der Beschäftigen im Industriebereich ging zurück (vgl. Kirsch-Soriano da Silva/Botzenhart 2022). Die Gemeinde insgesamt ist seit den 1970er Jahren durch eine stagnierende bis leicht schrumpfende Bevölkerungsentwicklung gekennzeichnet und umfasst heute 14.693 Einwohnerinnen und Einwohner (Stand: 2023, Quelle: Statistik Austria). Die Entwicklung der Gemeinde Zwentendorf an der Donau wurde ebenfalls durch in der Region entstandene Industriebetriebe geprägt – 1917 wurde die Pulverfabirk Skoda-Wetzler errichtet, es folgten eine Ölraffinerie, die von den 1940er Jahren bis Anfang der 1960er Jahre in Betrieb war, ein Chemiewerk an der Donau sowie eine Biospritanlage (vgl. Kirsch-Soriano da Silva/Botzenhart 2023). Anders als Ternitz erlebt die Gemeinde Zwentendorf allerdings bis heute ein sukzessives Bevölkerungswachstum, seit den 1940er Jahren und insbesondere seit den 1990er Jahren, und weist daher auch noch zunehmenden Wohnraumbedarf auf. Aktuell verfügt Zwentendorf über 4.181 Einwohnerinnen und Einwohner (Stand: 2023, Quelle: Statistik Austria).

Abb. 1 und 2: Siedlungsstrukturen aus den 1940er Jahren – Dreiersiedlung und Siedlung Erpersdorf © Caritas Stadtteilarbeit

Sowohl die „Siedlung III“ als auch die „Siedlung“ in Erpersdorf wurden als Wohnraum für Arbeiterinnen und Arbeiter der industriellen Betriebe und Fabriken geschaffen. In Ternitz gibt es mehrere Arbeiterinnen-

und Arbeitersiedlungen aus verschiedenen Jahrzehnten, der Großteil davon – ca. 1.420 Wohneinheiten – steht im Eigentum der gemeinnützigen Wohnbauvereinigung Schwarzatal, der ehemaligen Werksgenossenschaft von Schöller Bleckmann. Die Dreiersiedlung umfasste zu Beginn des Smart-Cities-Projekts im Jahr 2021 insgesamt 384 Wohnungen dieses Wohnungsbestands. Die Siedlung in Erpersdorf ist mit Abstand die größte Wohnsiedlung in der Gemeinde und macht mit 424 Wohneinheiten ca. 50% der Bewohnerinnen und Bewohner des Ortsteils Erpersdorf und ca. 20% der Bewohnerinnen und Bewohner der Gemeinde Zentendorf aus. Sie befindet sich im Eigentum der Ersten gemeinnützigen Wohnungsgesellschaft EGW.

3.2 Demographischer Wandel und Veränderung von Nachbarschaften

Mittlerweile hat sich die Wohnbevölkerung der Siedlungen dahingehend gewandelt, dass beide – im Vergleich zu ihrem Umfeld – einen hohen Anteil an Menschen mit Migrationsgeschichte haben. In der Dreiersiedlung haben knapp 70% der Bewohnerinnen und Bewohner eine österreichische Staatsbürgerschaft, 13,07% kommen aus Rumänien, 6,14% aus der Türkei, 4,55% aus Nordmazedonien und 7,13% aus anderen Staaten (Stand: 2021, Quelle: Meldedaten). Damit hat die Siedlung einen deutlich höheren Anteil an Bewohnerinnen und Bewohnern nicht österreichischer Staatsbürgerschaft als der Rest der Gemeinde Ternitz, wo 86,42% der Bewohnerinnen und Bewohner eine österreichische Staatsbürgerschaft besitzen (Stand: 2021, Quelle: Statistik Austria). In der Siedlung in Erpersdorf haben rund 65% die österreichische Staatsbürgerschaft, während 8,16% aus Bosnien Herzegowina, 6,40% aus Kroatien, 6,40% aus der Türkei, 3,01% aus Ungarn und je 1,38% aus Mazedonien, Serbien und der Slowakei und 1,13% aus Rumänien kommen, sowie in Summe 5,77% aus anderen Staaten (Stand: 2023, Quelle: Meldedaten). In der Gemeinde Zwentendorf haben im Vergleich dazu 85,90% eine österreichische Staatsbürgerschaft (Stand: 2023, Quelle: Statistik Austria). Der Anteil an Bewohnerinnen und Bewohnern mit ausländischer Staatsbügerschaft ist in beiden Gemeinden in den letzten Jahrzehnten gestiegen, wobei Zwentendorf vergleichsweise in den letzten knapp 20 Jahren einen noch deutlicheren Anstieg verzeichnete. Die beiden Siedlungen nahmen dabei jeweils einen überdurchschnittlichen Teil dieser Bewohnerinnen und Bewohner auf.

Darüber hinaus erfolgte ein Generationenwechsel. Es gibt nach wie vor ältere Bewohnerinnen und Bewohner, die – wie sie es schildern – praktisch „schon ihr ganzes Leben hier wohnen“, aber mittlerweile sind auch viele jüngere Haushalte und Familien in die Siedlungen gezogen. In der Dreiersiedlung sind heute die Altersgruppen der 30- bis 44-Jährigen und der 45- bis 64-Jährigen im Vergleich zur restlichen Gemeinde überdurchschnittlich vertreten, in der Siedlung in Erpersdorf die Gruppen der 15- bis 29-Jährigen, sowie der 30- bis 44 Jährigen. Ältere Menschen ab 65 Jahren bzw. ab 80 Jahren sind hingegen in beiden Siedlungen sogar unterrepräsentiert, was bestätigt, dass ein Bewohnerinnen-, Bewohner- und Generationenwechsel bereits stattgefunden hat. Ein Blick auf die Meldedaten der Dreiersiedlung zeigt auch, dass 42,77% in den letzten fünf Jahren in die Siedlung gezogen sind, 32,67% in den letzten sechs bis 15 Jahren, 10,89% leben seit 16-25 Jahren in der Siedlung, 6,14% seit 26-35 Jahren und nur 7,5% seit 36 Jahren oder länger (Stand: 2021, Quelle: Meldedaten). Dies verweist auf eine hohe Fluktuation der Bewohnerinnen und Bewohner, insbesondere in den letzten Jahren. Heute leben in den Siedlungen zudem nur mehr teilweise Beschäftigte der lokalen bzw. regionalen Industrie, sondern auch Personen, die in Dienstleistung und Gewerbe arbeiten, die in Ausbildung oder im Ruhestand sind sowie in einigen Fällen zu Arbeits- und Ausbildungsstätten pendeln.

Die berschriebenen Veränderungen führen dabei auch zu anderen Ansprüchen an Wohnen und Wohnraum – es zeigt sich ein Bedarf an einer gewissen Anzahl an barrierefreien Wohnungen, aber vor allem auch an unterschiedlichen Wohnungstypen. In Ternitz finden sich in der Dreiersiedlung überwiegend gleiche Wohnungstypen. In Zwentendorf gibt es aufgrund der unterschiedlichen Bauetappen – nach den 1940er Jahren wurde die Siedlung Erpersdorf mehrmals erweitert – auch verschiedene Wohnungsgrößen und Wohnungsgrundrisse, die unterschiedlichen Haushaltsanforderungen mehr Raum bieten. Darüber hinaus verändern sich durch den soziodemographischen Wandel die lokalen Nachbarschaften. In den Erzählungen der Bewohnerinnen und Bewohner finden sich soziale Distinktionen und eine formulierte Identifizierung mit bzw. Distanz zu verschiedenen Gruppen: so ist von den „Jüngeren“ und den „Älteren“ die Rede, den „Alteingesessenen“ und „Neuzugezogenen“, den „Österreicherinnen und Österreichern“ und „Menschen aus anderen Kulturkreisen/mit anderen Sprachen“. Die Nachbarschaften werden weniger als eine Gemeinschaft

wahrgenommen, sondern als heterogene Sozialräume, in denen Nähe und Zugehörigkeit, aber auch Ausschlussmechanismen erlebt werden. Und in denen insgesamt oft mehr Konfliktpotenzial verortet wird.

3.3 Energiewende und Klimaresilienz

Die Energieversorgung erfolgt in beiden Siedlungen in weiten Teilen noch mit Einzelöfen. Spätere Bauetappen in der Siedlung Erpersdorf in Zwentendorf wurden zum Teil mit Infrarotheizungen ausgestattet, Teile der Siedlung wurden an das Fernwärmenetz angeschlossen. Die Erfahrungen zeigen allerdings, dass nicht alle, die einen Fernwärmeanschluss besitzen, diesen tatsächlich nutzen, sondern teilweise auch mit den eigenen Einzelöfen weiter heizen. In beiden Siedlungen wird in der bestehenden Bausubstanz von Feuchtigkeit und Schimmel berichtet, wobei sich die Situation etwas unterschiedlich darstellt, je nachdem ob und wann schon Maßnahmen wie Fassadendämmung, Fenstertausch oder Sanierung von Dächern vorgenommen wurden.

Die Dachflächen bieten mit ihren Schrägen in beiden Siedlungen ein Potenzial für das Anbringen von Photovoltaik. Die Dachstühle könnten gleichzeitig für zusätzlichen Wohnraum oder eine Nutzung als Gemeinschaftsraum noch ausgebaut werden. Die Perspektive dafür ist – je nach Bevölkerungsentwicklung in der Gemeinde und damit verbundener starker oder schwacher Nachfrage nach Wohnraum – allerdings aktuell in den beiden konkreten Projekten sehr unterschiedlich.

In Hinblick auf die Erhöhung der Energieeffizienz zeigen sich in beiden Siedlungen Potenziale, insbesondere in Hinblick auf die Verbesserung der Dämmung und die Umstellung auf eine nachhaltige, zentrale Energieversorgung mit Nutzung erneuerbarer Energien. Eine Herausforderung, um die Siedlungen klimafitter zu gestalten, ist dabei allerdings, entsprechende Modernisierungs- und Sanierungsmaßnahmen zu konzipieren, die auch in bewohntem Zustand umgesetzt werden können. In Hinblick auf die Vermeidung von sommerlicher Überhitzung und die Verbesserung des Mikroklimas könnten Verschattungmöglichkeiten und Fassadenbegrünungen einen wesentlichen Beitrag leisten. Gerade in den Gemeinden im ländlichen Raum spielt zudem die Mobilität eine große Rolle bei Maßnahmen in Richtung Klimaneutralität. Der motorisierte Individualverkehr nimmt im Alltag vieler Bewohnerinnen und Bewohner aktuell eine bedeutende Rolle ein und die Stärkung alternativer Mobilitätsformen – durch unterschiedliche Bausteine – ist gefragt.

3.4 Modernisierung und Leistbarkeit

Bei der umfassenden und klimafitten Modernisierung ehemaliger Arbeiterinnen- und Arbeitersiedlungen im Bestand gemeinnütziger Wohnbauvereinigungen liegt die zentrale Herausforderung meist in der Finanzierung der Sanierungsmaßnahmen, wie im Bericht des vom Klima- und Energiefonds beauftragten Rahmenprozesses für die Modernisierung von Arbeiterinnen- und Arbeitersiedlungen festgehalten wurde (vgl. Rainer, Lang, Schreiner 2021). Einerseits sind häufig kaum finanzielle Rücklagen vorhanden, da die geleisteten Erhaltungs- und Verbesserungsbeiträge – für bestandserhaltende Maßnahmen, die laufende Brauchbarmachung und Verbesserung von Wohnungen bei Wiedervermietung, sowie teilweise auch großmaßstäblich in den Siedlungen gesetzte Maßnahmen wie Fassadendämmung, Erneuerung der Dachdeckung oder Fenstertausch – in den vergangenen Jahren weitgehend aufgebraucht wurden. Andererseits „unterliegen die Mieten laut WGG [Wohnungsgemeinnützigkeitsgesetz] strengen Obergrenzen, um insbesondere für Menschen mit geringem Einkommen leistbares Wohnen zu gewährleisten. Für umfassende Sanierungen sind daher weder die erforderlichen Finanzmittel angespart, noch können diese über künftige Mieteinnahmen refinanziert werden“ (Kirsch-Soriano da Silva/Botzenhart 2022). Die aus Landesmitteln gewährten Wohnbauförderungen für Sanierungen sind – im Vergleich zu den anfallenden Investitionskosten – oft zu gering und müssen durch gezielte nationale Förderprogramme mit Fokus auf eine Klima- und Energiewende ergänzt werden. Hier gilt es, neue Finanzierungs- und Fördermodelle zu entwickeln, um für Sanierungen von Siedlungen im gemeinnützigen Wohnungsbestand, die mehrdimensionale Maßnahmen in Richtung Klimaneutralität verfolgen, einen entsprechenden Rahmen zu schaffen. Konkrete Projekte fungieren dabei auch als wichtige Anlässe, um neue Handlungsansätze zu ermöglichen und zu fördern (ebd.).

Während aus ökologischer Sicht eine umfassende Revitalisierung bestehender Wohnanlagen anzustreben wäre, legt eine wirtschaftliche Betrachtung teilweise auch Abriss und Neubau solcher Siedlungen nahe. Auch das Wohnungsgemeinnützigkeitsgesetz WGG sieht aktuell vor, dass „insbesondere bei einem (…) hohen energetischen Sanierungsbedarf (...) in einer unternehmensinternen Kalkulation die Kosten einer

umfassenden Sanierung den Kosten eines Abbruchs samt den Kosten der Errichtung einer Baulichkeit in räumlicher Nähe (...) gegenüber zu stellen“ sind (vgl. Kirsch-Soriano da Silva/Botzenhart 2022). Um Sanierung als Handlungsoption zu stärken, müssen daher auch gesetzliche Rahmenbedingungen und Regelungen innerhalb der Gemeinnützigkeit – im Sinne einer ökologischen und sozialen Perspektive und im Sinne einer Lebenszyklus-Betrachtung – hinterfragt, neu bewertet und neu gedacht werden.

Die Gespräche mit den Menschen vor Ort in Ternitz und Zwentendorf zeigen, dass aus Sicht der Bewohnerinnen und Bewohner die Leistbarkeit häufig ein großes Qualitätsmerkmal der Siedlungen darstellt. Viele schätzen den günstigen Wohnraum bzw. sind auch darauf angewiesen. Häufig wurden – in Kooperation mit den Gemeinden – Haushalte mit geringeren Einkommen oder Personen, die Sozialhilfe beziehen, soger gezielt in die Siedlungen vermittelt. Die Leistbarkeit des Wohnens ist so – angesichts der Lebens- und Einkommenssituation einiger Bewohnerinnen und Bewohner – tatsachlich ein ganz wesentlicher Gesichtspunkt, der auch bei der räumlichen und baulichen Modernisierung und Weiterentwicklung der Siedlungen berücksichtigt werden muss.

4 PARTIZIPATIVE PROZESSGESTALTUNG

Herzstück ist in beiden Projekten eine partizipative Prozessgestaltung. Bewohnerinnen, Bewohner und lokale Akteurinnen und Akteure werden einbezogen, ihre Bedarfe, Anregungen und Ideen erhoben. Im Sinne einer emanzipatorischen Gemeinwesenarbeit soll Benachteiligungen entgegengewirkt werden und Menschen in den Siedlungen – uanbhängig von sozialer und kultureller Herkunft, Alter oder Geschlecht – dazu ermutigt werden, sich mit ihren Perspektiven einzubringen. Dabei werden verschiedene methodische Instrumentarien gewählt, um die Menschen vor Ort in ihren Lebenswelten anzusprechen.

4.1 Von-Tür-zu-Tür Befragung als Methode der Bedarfserhebung und Aktivierung

Ein erster Schritt der Kontaktaufnahme war in beiden Fällen die Durchführung einer Befragung. In der Dreiersiedlung wurde ein Fragebogen an alle Haushalte übermittelt, der ausgefüllt in einen Postkasten vor Ort eingeworfen werden konnte. Ergänzend dazu wurden persönliche Von-Tür-zu-Tür Gespräche (bzw. manchmal auch Von-Fenster-zu-Fenster Gespräche) geführt. Die persönlichen Gespräche orientierten sich dabei an der Methode der „Aktivierenden Befragung“ (Stoik 2009), bei der es einerseits darum geht, Bedarfe in Erfahrung zu bringen und in Maßnahmen einfließen zu lassen, andererseits darum, die Gesprächspartnerinnen und Gesprächspartner zu aktivieren, sich bei kommenden Aktivitäten selbst zu beteiligen. Bei den Gesprächsleitfäden wurden zudem Aspekte „Biographischer Gespräche“ integriert (vgl. Kirsch-Soriano da Silva/Bilalic 2021). Auch in Zwentendorf startete das Projekt mit einer explorativ angelegten aktivierenden Befragung.

Abb. 3 und 4: Bewohnerinnen- und Bewohnerbefragung in der Dreiersiedlung © Caritas Stadtteilarbeit

4.2 Nachbarschaftliche Begegnungsräume als Gelegenheit für Austausch und Gespräche

Eine weitere Herangehensweise, um ins Gespräch zu kommen, ist die Schaffung von nachbarschaftlichen Begegnungsräumen, wo informeller Austausch passiert und aktuelle Themen angesprochen werden können. In Ternitz wurde eine leer stehende Wohnung als „Nachbarschaftswohnung“ umgenutzt und dort zu

nachbarschaftlichen Treffen eingeladen. In der schönen Jahreszeit fanden Nachbarschaftscafés häufig mit Bänken und Tischen im Freiraum statt.


Abb. 5 und Abb. 6: Picknick in der Dreiersiedlung © einszueins, Radcheck in der Siedlung Erpersdorf © Caritas Stadtteilarbeit

Auch in der Siedlung in Erpersdorf wurden seit Projektstart im Frühjahr 2023 erste nachbarschaftliche Veranstaltungen im Freiraum organisiert, wie beispielsweise ein „Radcheck“ oder ein „Punsch mit Energiespartipps“. Diese Settings zogen schnell die Aufmerksamkeit der Bewohnerinnen und Bewohner auf sich und wurden für ein Zusammenkommen genutzt. Bei den nachbarschaftlichen Interaktionen entstehen dabei nicht nur Austausch, sondern auch neue Ideen. Zudem tragen sie zu einer Stärkung des Sozialkapitals bei, da durch „Bonding, Bridging, Linking“ (nach dem Konzept von Robert D. Putnam) auch neue Netzwerke innerhalb und zwischen Bewohnerinnen- und Bewohnergruppen sowie zu Einrichtungen in der Gemeinde geknüpft werden. Dies zeigt auch breitere soziale Wirkungen, da mit Begegnungen und Interaktionen einer erlebten Einsamkeit und Isolation entgegengewirkt wird und gleichzeitg Empowerment und soziale Teilhabe auf lokaler Ebene gefördert werden. Dabei können bestehende Orte – wie aktuell leer stehende Wohnungen – genutzt und zugänglich gemacht werden, aber auch neue Orte beispielsweise durch Treffpunkte im Freiraum geschaffen werden.

4.3 Zukunftswerkstatt als Format für Dialog und Sammlung von Ideen

In der Siedlung in Erpersdorf wurde schon bald nach Beginn des Projekts – im September 2023 – eine große Zukunftswerkstatt organisiert. Dabei wurde mitten in der Siedlung ein großes Zelt aufgebaut und einen Nachmittag lang zu Ideen für die Zukunft diskutiert. An Thementischen zu „Wohnraum & Gebäude“, „Freiraum & Ökologie“, „Energie & Klimaschutz“, „Zukunft der Mobilität“ sowie „Nachbarschaft & Miteinander“ konnten Bewohnerinnen und Bewohner der Siedlung mit Expertinnen und Experten aus verschiedenen Fachrichtungen in Dialog treten und die eigenen Anregungen, Bedarfe, Fragen und Verbesserungswünsche artikulieren. Die Ergebnisse der Zukunftswerkstatt bilden – gemeinsam mit den Ergebnissen der Befragung sowie der interdisziplinären Potenzialanalyse der Siedlung durch die beteiligten Fachexpertinnen und Fachexperten – eine wichtige Grundlage für die Entwicklung und Umsetzung kommender Maßnahmen.


Abb. 7 und 8: Zukunftswerkstatt in der Siedlung Erpersdorf © Caritas Stadtteilarbeit

4.4 Zusammenarbeit mit lokalen Akteurinnen und Akteuren

Die Zusammenarbeit mit lokalen Akteurinnen und Akteuren, das Stärken und Aufbauen von lokalen Potenzialen und Expertisen ist ebenalls ein zentraler Baustein in der partizipativen Prozessgestaltung. Dies können zivilgesellschaftlich organisierte Vereine und freiwillig Engagierte sein, aber auch Vertreterinnen und Vertreter lokaler Betriebe, sozialer Einrichtungen und der Gemeinden. In Ternitz ist zum Beispiel der Pensionistinnen- und Pensionistenverein ein wichtiger Kooperationspartner. Dieser betreibt vor Ort das „Volkshaus", einen Veranstaltungsort, in dem größere Treffen im Rahmen des Projekts stattfinden und sich auch Möglichkeiten für weitere Projektaktivitäten eröffnen. So gab es dort Nachbarschaftsaktivitäten wie Kranzbinden und Kekse backen, Informationsveranstaltungen zur Zukunft der Siedlung, und – während der dreiwöchigen Summer School „Common Space Ternitz" im Juli 2022 – wurde sogar eine Gruppe von Studierenden für ihre Arbeit vor Ort dort einquartiert. In Zwentendorf sind Vertreterinnen und Vertreter der Gemeinde und lokale Multiplikatorinnen und Multiplikatoren wie eine engagierte Bewohnerin und Gemeinderätin, die regelmäßig selbst in der Siedlung Sprechstunden anbietet, wichtige Kommunikatorinnen und Kommunikatoren des Projekts im Alltag vor Ort. Engagierte Personen und Einrichtungen rund um die Siedlungen erweisen sich in beiden Projekten als wesentliche Partnerinnen und Partner, die dabei unterstützen, verschiedene Menschen anzusprechen, zu erreichen und zu involvieren.

4.5 Arbeit an der Identität der Siedlungen

Eine wesentliche Säule ist in beiden Siedlungen zudem die Arbeit an ihrer Identität. Beide sind in der jeweiligen Gemeinde ein Stück weit mit dem Image eines „sozial schwächeren" Quartiers behaftet. Wobei die persönlichen Gespräche häufig ein ganz anderes Innenbild zeigen: von Bewohnerinnen und Bewohnern, die gerne in den Siedlungen leben und ihre Qualitäten – wie große Grünräume und kleinräumige nachbarschaftliche Kontakte auf einzelnen Stiegenhäusern und Häusern – sehr schätzen. Die Frage der Identität beginnt dabei schon bei der Namensgebung. Die ursprünglich als „Siedlung III" benannte Siedlung in Ternitz wird mittlerweile von den Menschen als „Dreiersiedlung" bezeichnet, ein Ort der in den Köpfen vieler präsent ist, da zahlreiche Ternitzerinnen und Ternitzer schon selbst einmal in ihrem Leben hier gewohnt haben oder zumindest jemand kennen, der hier wohnt oder gewohnt hat. Die Siedlung in Erpersdorf hingegen hat tatsächlich keinen Namen und auch die Adressbildung führt teilweise zu Verwirrungen bzw. werden Adressen – mit ihren Bezeichnungen „Block I, II, III,…" – selbst von Einsatzdiensten manchmal nicht gefunden. Die Auseinandersetzung mit der Identität der Siedlung, ihrer Geschichte, aber auch ihren Qualitäten und Zukunftspotenzialen, ist daher ein wichtiger Anknüpfungspunkt für den gesamten Prozess der Weiterentwicklung.

Ein Schritt in der Sichtbarmachung der Siedlungen und ihrer Potenziale ist dabei auch die Gestaltung eines Webauftritts. Dieser informiert über das jeweilige Projekt und zeigt gleichzeitig, dass in den Siedlungen etwas passiert und spannende Veranstaltungen organisiert werden. Einblicke in die Gestaltung der Websites und aktuelle Veranstaltungen in Ternitz und Zwentendorf finden sich unter www.dreiersiedlung.at und www.zukunftsiedlung.at.

5 DIE SIEDLUNGEN AUS SICHT IHRER BEWOHNERINNEN UND BEWOHNER

In beiden Siedlungen wurden über mehrere Monate Befragungen und partizipvative Formate durchgeführt. Deren Auswertung zeigt ein Porträt der jeweiligen Siedlung, wie sie die Bewohnerinnen und Bewohner wahrnehmen.

5.1 Die Dreiersiedlung in Ternitz in der Wahrnehmung von Bewohnerinnen und Bewohnern

Zwischen Februar und März 2022 wurden schriftliche Fragebögen an alle Haushalte in der Siedlung verteilt. Es wurden 18 schriftliche Fragebögen ausgefüllt und 7 persönliche Interviews durchgeführt. Ergänzend wurden 10 weitere Gespräche in der Siedlung geführt. Ziel war es, mehr über die Perspektiven zum Wohnen in der Dreiersiedlung und die Bedarfslagen der Bewohnerinnen und Bewohner zu erfahren sowie ihre Ideen für die Zukunft der Siedlung einzuholen.

Die Siedlung als günstiger Wohnraum, in der die Menschen gerne leben

Den allermeisten Befragten gefällt es gut, in der Dreiersiedlung zu wohnen. Als besondere Vorteile werden der günstige Wohnraum und die ruhige Lage wahrgenommen. Die Nachbarschaft bewerten die meisten ebenfalls als gut, manche als mäßig. Viele Gesprächspartnerinnen und Gesprächspartner geben an, hin und

wieder zu ihren Nachbarinnen und Nachbarn Kontakt zu haben, einge auch regelmäßig oder sogar täglich. Ungefähr die Hälfte der Befragten wünscht sich mehr Austausch innerhalb der Siedlung. Wenn es Gemeinschaftsräume gäbe, würden die meisten diese gerne als Bibliothek, als Fahrrad- oder Kinderwagenraum, als Bewegungsraum, als Arbeitsraum, Atelier oder Werkstatt, sowie als Spielraum für Jung und Alt nutzen. In Bezug auf tatsächliche Veränderungen haben – angesichts des Leerstands, wo lange nichts passiert ist – viele aber wenig Hoffnung.

Gärten als Qualität und Wunsch nach Sitzgelegenheiten im Freiraum

Als besondere Qualität werden die Gärten und Freiräume in der Siedlung empfunden. Eine große Mehrheit der Befragten verfügt über einen eigenen Mieterinnen- und Mietergarten und nutzt diesen täglich oder jedenfalls wöchentlich. Der Garten dient ihnen als Ort für Erholung und Entspannung, zum Zusammensitzen, zum Anbau von Gemüse und Obst, aber auch als Ziergarten. Ansonsten halten sich die Menschen auch zum Wäsche trocknen, zum Ausruhen und Sitzen, zum Spazieren und Flanieren oder zum Spielen im Freiraum auf. Es gibt einen großen Wunsch nach mehr Sitzgelegenheiten im Freiraum, sowie von manchen auch nach mehr bzw. besseren Spielplätzen.

Überwiegende Zufriedenheit mit Wohnungstyp, aber Bedarf nach Barrierefreiheit

Unter den Befragten herrscht eine relative hohe Zufriedenheit mit der Wohnungsgröße, der Belichtung, sowie der Anzahl und Aufteilung der Zimmer. Es handelt sich allerdings mehheitlich um Ein- oder Zwei-Personenhaushalte. Eine befragte Person mit vier Personen im Haushalt empfindet die Wohnung als zu klein. Mit der fehlenden Barrierefreiheit ist etwa ein Drittel der Befragten wenig oder nicht zufrieden.

Heizen mit Einzelöfen und Phänomene von Energiearmut

Von den Bewohnerinnen und Bewohnern wird die Energieversorgung und insbesondere das Heizen im Winter als große Herausforderung wahrgenommen. Die meisten der Befragten heizen mit Holz oder Strom, manche auch mit Öl, Gas, Kohle/Koks und Pellets. Deutlich mehr als die Hälfte der befragten Bewohnerinnen und Bewohner heizt einzelne Räume nicht oder bedeutend weniger. Etwas mehr als die Hälfte der Befragten gibt an, von Feuchtigkeit betroffen zu sein. Die Heizkosten werden im Verhältnis zum Haushaltseinkommen von den meisten als hoch empfunden, von manchen sogar als sehr hoch. Die Raumtemperatur im Winter wird dabei als größere Herausforderung wahrgenommen, mit der Raumtemperatur im Sommer ist die Mehrheit zufrieden. Sowohl die im Vergleich zum Haushalsteinkommen hohen Energiekosten als auch die teilweise nicht beheizten Räume verweisen dabei auch auf das Vorhandensein von Energiearmut bei einem Teil der Befragten.

Zu wenig Geschäfte und Gastronomie, geringe Nutzung öffentlicher Verkehrsmittel

In den letzten Jahren haben einige Geschäfte und Gastronomieangebote geschlossen. Dementsprechend sind viele der Befragten mit der Nahversorgung wenig oder nicht zufrieden. Die Infrastruktur an Schulen und Kindergärten wird als zufriedenstellend empfunden. Die Meinung in Hinblick auf Angebote im Bereich Gesundheitsversorgung, Betreuung und Pflege, Sport- und Freizeitangebote, sowie Kulturangebote ist sehr gemischt. Besonders dringend bräuchte es laut vielen Gesprächspartnerinnen und Gesprächspartnern ein Lebensmittelgeschäft. Die eigenen Alltagswege werden teils zu Fuß zurückgelegt, besonders häufig aber mit dem Auto oder Taxi. Die öffentlichen Verkehrsmittel wie auch das Fahrrad werden von den Befragten kaum genutzt.

5.2 Die Siedlung Erpersdorf in Zwentendorf in der Wahrnehmung von Bewohnerinnen und Bewohnern

Zwischen Mai und November 2023 wurden erste Befragungen mit insgesamt 17 Bewohnerinnen und Bewohnern durchgeführt. Im September 2023 fand zudem eine Zukunftswerkstatt mit 80 Teilnehmerinnen und Teilnehmern statt, die Gelegenheit gab, Bedürfnisse und Ideen einzubringen.

Modernisierung der Wohnungen, aber Leistbarkeit soll erhalten bleiben

Viele Menschen sind für eine Modernisierung, betonen aber, dass die Leistbarkeit der Wohnungen erhalten bleiben muss. Es gibt ein Interesse an Balkonen, sowie an eigenen Gärten bzw. einer direkten Verbindung in den Hof. Konkrete Wünsche betreffen auch die Barrierefreiheit, Plätze für Rollatoren und Kinderwägen, Räume für Alt und Jung. Bei den Wohnungen wird ein außenliegender Sonnenschutz gegen sommerliche Hitze sowie die Verbesserung der Schalldämmung zu den Nachbarwohnungen angeregt. Eine

Fassadenbegrünung wird gemischt gesehen – einige haben auch Angst vor Ungeziefer oder machen sich Sorgen um die Pflege. Manchen erscheint eine Kellersanierung wichtiger als der Dachgeschoßausbau.

Mehr Aufenthaltsqualität im Freiraum, Verbesserung der Müll- und Parkplatzsituation

Zahlreiche Bewohnerinnen und Bewohner wünschen sich mehr Aufenthaltsqualität im Freiraum – durch Blumen, Naschhecken, Sitzgelegenheiten und Tische. Es gibt auch Interesse an Hochbeeten sowie der Pflanzung von mehr Schatten spendenden Bäumen, sowie an der Nutzung von Eigengärten. Einige haben den Wunsch nach besseren Spielplätzen, einem Skater- und Trainingsplatz. Verbessert werden sollte nach Meinung vieler insbesondere die Müll- und Parkplatzsituation. Neben baulichen Maßnahmen werden auch ein Siedlungsflohmarkt oder Verkehrserziehung für Kinder vorgeschlagen.

Umstieg auf Fernwärme von manchen nicht gewünscht, Interesse an Photovoltaik

Geheizt wird unterschiedlich – mit Fernwärme, Einzelöfen mit Pellets/Hackschnitzel oder Infrarotheizungen. Bei der Fernwärme wird von teilweise hohen Nachzahlungen berichtet. Einige Bewohnerinnen und Bewohner nutzen daher den bereits hergestellten Fernwärmeanschluss nicht. Umgekehrt funktioniert die Wärmeregelung bei den Einzelöfen allerdings deutlich weniger gut. Den meisten ist in Summe vor allem das Energiekosten sparen wichtig. Teilweise sind Fenster nicht dicht, wird Feuchtigkeit oder Schimmel beobachtet. Insbesondere an einer Photvoltaik Anlage haben einige Interesse, manche sogar daran, sich finanziell zu beteiligen.

Viele Alltagswege zu Fuß und mit dem Rad, Verbindungswege zum Bahnhof Tullnerfeld

Der nächste Supermarkt ist zu Fuß erreichbar, die Alltagswege in der Nähe werden von vielen mit dem Fahrrad zurückgelegt. Interesse gibt es an geschützten Radabstellplätzen, Lastenfahrrädern und E-Rollern zum Ausborgen, sowie an E-Ladestationen. Sowohl die Verbesserung von Busverbindungen als auch von Radwegen, insbesondere zum Bahnhof Tullnerfeld, wird als wichtig angesehen. Zur Durchsetzung einer Geschwindigkeitsbeschränkung wären Bodenschwellen in der Siedlung eine wichtige Maßnahme.

Heterogene Nachbarschaften und Bankerl vor der Haustür als Treffpunkte

Einge haben den Wunsch nach Nachbarschaftsfesten und mehr Kontakt zu den Nachbarinnen und Nachbarn, andere sind zufrieden mit den Kontakten in ihrem Umfeld. Insbesondere auf den Stiegenhäusern oder in einzelnen Blöcken wird dabei kleinräumlich von einer besonders guten Nachbarschaft erzählt. Andere thematisieren eine höhere Fluktion und Gruppen aus verschiedenen Sprach- und Kulturkreisen, die miteinander wenig Kontakt haben oder auch Konflikte austragen. Die Reinigung der Stiegenhäuser sowie Unklarheiten über Zuständigkeiten führen teilweise ebenfalls zu Unstimmigkeiten. Einige wünschen sich eine Hausbetreuung bzw. Ansprechperson direkt in der Siedlung, sowie eine verständlich aufbereitete und gut sichtbare Hausordnung. An manchen Stiegenhäusern gibt es ein Bankerl vor der Haustür, das als Treffpunkt dient und gerne zum Plaudern mit Nachbarinnen und Nachbarn genutzt wird.

6 ENTWICKLUNG UNTERSCHIEDLICHER HANDLUNGSSTRATEGIEN

Basierend auf den fachlichen Analysen und den von Bewohnerinnen und Bewohnern und lokalen Akteurinnen und Akteuren eingebrachten Themen und Perspektiven, wurden bzw. werden in beiden Siedlungen unterschiedliche Handlungsstrategien entwickelt. Die Prozesse in beiden Siedlungen sind akuell noch im Laufen, beispielhaft werden ausgewählte bisher relevante Handlungsansätze beschrieben.

6.1 Momente der Aufmerksamkeit und Sichtbarkeit erzeugen

Eine zentrale Handlungsstrategie an beiden betrachteten Orten ist es, mehr Aufmerksamkeit und Sichtbarkeit für die Siedlungen zu schaffen – sowohl bei den Bewohnerinnen und Bewohnern als auch in der Gemeinde und darüber hinaus. In der Dreiersiedlung wurde in Kooperation mit dem Forschungsbereich Städtebau der TU Wien und Mostlikely Architektur eine Summer School organisiert. Diese brachte im Sommer 2022 eine Gruppe von rund 20 Architektur Studierenden in die Siedlung, die für drei Wochen vor Ort wohnten und arbeiteten. Unter dem Motto „Common Space Ternitz“ sowie basierend auf artikulierten Bedarfslagen von Bewohnerinnen und Bewohnern wurden gestalterische Elemente für die Siedlung entworfen und in Holzbauweise von den Studierenden selbst errichtet. Auf diese Weise entstanden multifunktionale Freiraum-Möblierungen, die an unterschiedlichen Orten in der Siedlung zum Zusammenkommen und Verweilen einladen und seitdem von den Bewohnerinnen und Bewohnern gerne angeeignet und genutzt werden. Eine feierliche Eröffnung der gebauten Produkte der Summer School lud zudem Vertreterinnen und Vertreter der

Gemeindepolitik in die Siedlung. Das Medienecho schuf auch über die lokale Umgebung hinaus Öffentlichkeit für die Aktivitäten in der Dreiersiedlung.


Abb. 9 und 10: Eröffnung Möblierung Summer School „Common Space Ternitz“ in der Dreiersiedlung © einszueins

In Zwentendorf wurde bereits nach wenigen Monaten eine große Zukunftswerkstatt – als sichtbarer Projektauftakt – organisiert. Mitten in der Siedlung Erpersdorf wurde ein Zelt aufgebaut, interessierte Menschen wurden zum Vorbeikommen und Mitmachen eingeladen. Die Gemeinde war ebenso vertreten, wie zahlreiche Bewohnerinnen und Bewohner. Insgesamt nutzten rund 80 Teilnehmerinnen und Teilnehmer die Gelegenheit, bei der Zukunftswerkstatt von „ZUSIE – Zukunft Siedlung“ dabei zu sein. Auch über die Zukunftswerkstatt gab es im Anschluss öffentlichkeitswirksame Nachberichte in den Kommunikationskanälen der Gemeinde und in den Medien, sodass auch weitere Interessierte vom Projekt erfuhren. Durch die Projektwebsites und Stakeholder Workshops werden Erfahrungen aus beiden Projekten zudem laufend weitergegeben. Dies trägt zu einer wachsenden, mittlerweile auch überregionalen Bekanntheit der Siedlungen sowie der Projekte bei.

6.2 Auf lokale Entwicklungen reagieren - Leerstand umutzen oder Wohnraum ausbauen

Eine weitere wesentliche Handlungsstrategie baut darauf, auf spezifische lokale Entwicklungen zu reagieren. So geht es in der Dreiersiedlung stärker darum, den Leerstand von Wohneinheiten und Gebäuden strategisch für eine umfassendere Umgestaltung der Siedlung zu nutzen. Die derzeit geringere Nachfrage nach Wohnraum in Ternitz eröffnet Möglichkeiten, anstelle von Wohnungen andere Einrichtungen und Infrastrukturen in die Siedlung zu bringen, sowie mit größeren Wohnungsgrundrissen auch eine Diversifizierung des Wohnungsmixes und eine Reduktion der Anzahl an Wohneinheiten zu schaffen. Vor diesem Hintergrund wurden bereits in den vergangenen Jahren seitens der Wohnbauvereinigung bestimmte Teile der Siedlung, die sich in baulich schlechterem Zustand befanden, nicht wieder vermietet. Gespräche mit der Gemeinde über mögliche soziale Infrastrukturen, die in der Siedlung in Zukunft Platz finden könnten, zeigten den Bedarf nach einem neuen Kindergarten auf. Im Jahr 2023 wurde daher ein Bauplatz an die Gemeinde veräußert. Anstelle einer leer stehende Gebäudezeile entsteht dort nun ein Kindergarten, der voraussichtlich noch 2024 seinen Betrieb starten wird. Für eine erste Bauphase der Modernisierung der restlichen Siedlung wurde beim Land Niederösterreich um Sanierungsförderung angesucht, die Anfang 2024 eine Zusage erhielt. So können erste Sanierungsschritte im Detail geplant und realisiert werden. Diese betrefffen insbesondere die weiteren bereits leerstehenden Zeilen, in denen auch umfassendere bauliche Maßnahmen – in Richtung ökologischer Nachhaltigkeit und zeitgemäßem Wohnen – gesetzt werden können. Ihnen sollen im Anschluss sukzessive weitere Modernisierungsmaßnahmen in der gesamten Siedlung folgen.

In der Siedlung Erpersdorf steht die Entwicklung eines Sanierungskonzepts für die Siedlung erst am Beginn. Bereits jetzt zeigt sich allerdings, dass die wachsende Bevölkerung der Gemeinde eine andere Ausgangssituation darstellt, in der die Schaffung von zusätzlichem Wohnraum – beispielsweise durch den Ausbau von Dachgeschossen – durchaus in Erwägung gezogen wird.

6.3 Wohnraum für verschiedene Bedarfe gestalten und neue Wohnformen integrieren

Mit neuen Wohnfomen können potenziell auch neue Bewohnerinnen und Bewohner für die Siedlungen angesprochen sowie insgesamt auf die Bedarfe unterschiedlich zusammengesetzter Haushalte besser reagiert werden. So bieten Umgestaltungen die Möglichkeit für barrierefreie Wohnungen, zum Beispiel auch

kombiniert mit betreuten bzw. betreubaren Wohnungsangeboten oder Formen des Generationenwohnens. Dies kann Chancen für ältere oder mobilitätseingeschränkte Bewohnerinnen und Bewohner bieten, aber auch für generationen-übergreifende Wohngemeinschaften, die sich u.a. durch den Zuzug von Familienangehörigen oder Bekannten aktueller Bewohnerinnen und Bewohner bilden könnten. Gerade bei aktuell leerstehenden Gebäudezeilen sind Umbauten, die auch in Wohnungsgrundrisse und Erschließung stärker eingreifen, möglich. So kann auf verschiedene Wohnraumbedarfe mit der Schaffung unterschiedlicher Wohnungstypen reagiert werden. In der ersten Bauphase in der Dreiersiedlung soll so ein Fokus auf einen vielfältigeren Wohnungsmix sowie Barrierefreiheit gelegt werden. Die entstehenden Wohnungen könnten damit sowohl für größere Familien als auch für ältere Bewohnerinnen und Bewohner aus dem restlichen Siedlungsbestand von Interesse sein.

Bei einer weiteren Gebäudezeile der Dreiersiedlung werden derzeit Interessentinnen und Interessenten für eine Baugruppe bzw. für gemeinschaftliches Wohnen gesucht. Auch diese Wohnform kann potenziell neue Bewohnerinnen und Bewohner anziehen und stellt – mit dem üblicherweise stärker auf Engagement in Gemeinschaft und Nachbarschaft setzenden Konzept – zudem eine Chance für die gesamte Siedlung dar. Gemeinsam mit den zukünftigen Bewohnerinnen und Bewohnern soll partizipativ geplant werden, können Gemeinschaftsräume und Gemeinschaftsgärten entstehen sowie insgesamt eine lebendige nachbarschaftliche Dynamik.

6.4 Rechts- und Finanzierungsmodelle diversifizieren

Die Etablierung eines diversifizierten Wohnungsmixes kann auch mit unterschiedlichen Rechts- und Finanzierungsmodellen einhergehen. Während der Großteil der Wohnungen in beiden Siedlungen in Eigentum und Verwaltung der gemeinnützigen Wohnbauvereinigungen bleiben soll, sind in ausgewählten Bereichen auch alternative Modelle denkbar. Findet sich in der Dreiersiedlung beispielsweise eine Baugruppe, so könnte diese einen Verein gründen, der sich möglicherweise auch an Investitionen beteiligt. Zudem könnten im Zuge des umfassenden Umbaus von Gebäudezeilen auch Miet-Kauf-Modelle für manche Wohnungen bzw. manche Bewohnerinnen und Bewohner eine Option werden. In Summe gilt es, aus den oben geschilderten Dynamiken und den konkret anvisierten Maßnahmen, auch spezifische Strategien für die Finanzierung von Modernisierungsmaßnahmen in den jeweiligen Siedlungen zu erarbeiten.

Dabei spielen einerseits Sanierungsförderungen aus der Wohnbauförderung des Landes eine Rolle, andererseits zusätzliche Bundesförderungen wie „Raus aus Öl und Gas“ oder Förderungen für die Nutzung erneuerbarer Energien und die Errichtung von Photovoltaik. Darüber hinaus bringen Potenziale für Dachgeschossausbau oder Nachverdichtung auch Potenziale für eine bessere Finanzierung von Investitionen in eine Siedlung mit sich. Umgekehrt kann auch ein Rückbau und eine anderweitige Nutzung Teil einer ökonomischen Strategie sein – so kann der Verkauf einer Liegenschaft für die Errichtung eines Kindergartens insgesamt dazu beitragen, die noch kommenden Sanierungsmaßnahmen in der Dreiersiedlung leistbarer zu machen. Ein Blick auf die Beispiele zeigt daher, dass es auch in Hinblick auf Rechts- und Finanzierungsmodelle gewisse Mischformen sein können, welche die Finanzierbarkeit von Maßnahmen ermöglichen.

Ein Blick auf internationale Best Practice Beispiele aber auch auf die Geschichte der Siedlungen selbst wirft zudem die Frage auf, inwieweit in Zukunft auch Do-it-yourself Konzepte verstärkt eine Rolle spielen können. In der Vergangenheit war es häufig gängige Praxis, dass Wohnungsverbesserungen bis hin zu Kategorieverbesserungen von Bewohnerinnen und Bewohnern selbst durchgeführt wurden. Bevor auf gesetzlicher Ebene der Erhaltungs- und Verbesserungsbeitrag eingeführt wurde, hatten Eigentümerinnen und Eigentümer häufig auch gar nicht entsprechende Rücklagen, um in diese Verbesserungen angemessen zu investieren. Im Spannungsfeld zwischen der technischen Eignung und Prüfung von selbst gesetzten Maßnahmen und der Eigeninitiative im Sinne von Leistbarkeit, könnte diese Herangehensweise daher auch in Zukunft neu verhandelt werden.

6.5 Prototypische Maßnahmen für Klimaneutralität entwickeln und multiplizieren

In der Siedlung in Erpersdorf gehen die ersten Überlegungen in die Richtung, prototypische Maßnahmen in Richtung Klimaneutralität zu entwickeln und zu erproben, die später auch multipliziert werden können. Ideen dafür sind eine Moblitätsstation mit Klimapergola – also ein multifunktionales Element im Freiraum, das einen Ort mit Beschattung mit einem Verleih von Mobilitätsangeboten und E-Ladestationen mit

Photovoltaik miteinander verknüpfen könnte. Ein weiteres multifunktionales Element könnte ein Klimabalkon sein, der nicht nur einen erweiterten wohnungsbezogenen Freiraum, sondern auch Begrünung mit Grau- oder Regenwassermanagement sowie möglicherweise ebenfalls Photovoltaik verbindet.

Für eine ökologisch nachhaltige Umstellung der Energieversorgung gibt es verschiedene, sich laufend weiter entwickelnde technologische Möglichkeiten, die – gegebenenfalls ebenfalls aufbauend auf Prototypen – jeweils auf die gesamten Siedlungen ausgerollt werden könnten. Die Maßnahmen im Bereich der Energieeffizienz können vielfältig sein – von Dämmung in Kombination mit Bauteilaktivierung für Heizung oder Kühlung, über die Implementierung von Erdwärme- oder Luftwärmepumpen bis zur Nutzung von Sonnenenergie mittels Photovoltaik, um nur einige zu nennen. Begleitend zu den technischen Lösungen gibt es dabei ebenfalls verschiedene Modelle, wie Errichtung und Betrieb organisiert und finanziert werden können. Alleine bei Photovoltaik Anlagen reicht die Bandbreite von einer Verpachtung der Dachflächen an einen professionellen Betreiber über die Möglichkeit für Wohnbauträger, selbst als Errichter und Betreiber zu agieren, bis zur Bildung von bzw. den Anschluss an Energiegemeinschaften. In Hinblick auf Mobilität erfordern die meisten Maßnahmen eine Kooperation mit der Gemeinde – wie etwa bei der Verbesserung von Radwegen oder dem Ausbau öffentlicher Verkehrsverbindungen in Ortschaft, Gemeinde und Region.

6.6 Aufenthaltsqualitäten im Freiraum stärken und Treffpunkte für die Nachbarschaft schaffen

Die Freiräume stellen in den beiden betrachteten Siedlungen eine besondere Qualität dar. In der Dreiersiedlung haben sich über die Jahrzehnte teilweise auch Mieterinnen- und Mietergärten etabliert. Solche könnten in manchen Flächen auch eine Option für die Siedlung in Erpersdorf sein. In beiden Siedlungen bieten die Freiräume zudem auch Potenziale für Treffpunkte und somit für Begegnungsorte in der Nachbarschaft. Eine Handlungsstrategie ist es, diese Verweilqualitäten auf unterschiedlichen Ebenen – durch Sitzgelegenheiten, Spiel- und/oder Sportbereiche sowie Bepflanzung – für unterschiedliche Nutzerinnen und Nutzer zu stärken. Die im Rahmen der Summer School in Ternitz entstandene Freiraum-Möblierung, die heute von vielen Bewohnerinnen und Bewohnern gerne genutzt wird, bekräftigt diese Potenziale. Einzelne Plauderbankerl, wie sie es schon jetzt neben manchen Hauseingängen in der Siedlung in Erpersdorf gibt und die – Schritt um Schritt – im Rahmen des Projekts multipliziert und erweitert werden könnten, verdeutlichen dies ebenfalls. Geplant ist in Erpersdorf zudem auch ein Zukunftsraum, der – rund um einen Container im Freiraum – Stützpunkt für Partizipationsformate und Nachbarschaftsaktivitäten während des Projekts werden soll.

7 LERNERFAHRUNGEN UND FAZIT

Auf Basis des bisherigen Stands der beiden Forschungs- und Entwicklungsprojekte, können folgende übergreifende Lernerfahrungen skizziert werden.

7.1 Spezifische Bedingungen als lokale Potenziale für identitätsstiftende Entwicklungswege

Obwohl Siedlungen aus einer bestimmten Zeit auch ähnliche Strukturen und Herausforderungen aufweisen, unterliegen sie doch auch spezifischen Rahmenbedingungen. So erfordern unterschiedliche Dynamiken von Wachstum oder Schrumpfung einer Gemeinde beispielsweise unterschiedliche Handlungsstrategien. Und auch die Potenziale der lokalen Wahrnehmungen und Akteurinnen und Akteure bringen unterschiedliche Ressourcen mit sich. Interessant ist, dass das subjektive Empfinden der Wohnqualität bei den Menschen, die in den Siedlungen leben, häufig deutlich höher ist, als von einer Außenperspektive angenommen. Die Herausarbeitung der eigenen Identität, das Generieren von positiven Aufmerksamkeiten und auch die Sichtbarkeit der Siedlungen als besondere Orte kann daher ein erster Schritt sein, noch vor ersten baulichen Maßnahmen.

7.2 Bewertung des Wohnungs- bzw. Siedlungsbestands und Rahmenbedingungen im WGG

Für die gemeinnützigen Wohnbauvereinigungen, die einen großen älteren Wohnungs- beziehungsweise Siedlungsbestand haben, ist die Entwicklung einer Strategie für den Umgang mit diesem Bestand eine wesentliche Handlungsgrundlage. Ansatzpunkte, wie dieser Bestand nach unterschiedlichen Kriterien – wirtschaftlich, ökologisch und sozial – bewertet und weiterentwickelt werden kann, sind dafür von zentraler Bedeutung. Neben einer ökonomischen Perspektive gilt es dabei auch, die ökologischen und sozialen Kriterien zur Beurteilung von möglichen Maßnahmen zu stärken und – im Sinne einer Lebenszyklusbetrachtung – neue Wege zu gehen. Erfahrungen aus Pilotprojekten für den Bestand, die

beispielsweise im Rahmen von Smart-Cities-Projekten umgesetzt werden, sollten sich in Folge im weiteren Gebäudebestand von Wohnbauvereinigungen sowie auch in etwaigen Anpassungen von Regelungen im Wohnungsgemeinnützigkeitsgesetz WGG niederschlagen.

7.3 Förderlandschaft und Förderung von Begleit- und Enticklungsprozessen

Die bisherigen Erfahrungen in Hinblick auf die Finanzierung umfassender Modernisierungsmaßnahmen in ehemaligen Arbeiterinnen- und Arbeitersiedlungen zeigen, dass – zum derzeiten Zeitpunkt und angesichts der aktuellen Herausforderungen in Hinblick auf eine Klima- und Energiewende – öffentliche Förderungen essentiell sind, um die erforderlichen Adpatierungs- und Sanierungsmaßnahmen tatsächlich auch in großem Maßstab voranzutreiben. Eine laufende Weiterentwicklung der Förderlandschaft ist in dieser Hinsicht besonders wichtig. Die beiden Smart-Cities-Projekte verweisen darauf, dass neben der Förderung von baulichen und technischen Maßnahmen auch eine Förderung des Begleitprozesses von Bedeutung ist. Entsprechende Förderschienen sollten daher in Zukunft auch Partizipation und Kommunikation unterstützen, die – gerade in Siedlungen mit geringeren Einkommen und höherer Diversität – für die Beteiligung bei diesen Maßnahmen, sowie die Gestaltung von sozialen und nachbarschaftlichen Interventionen wesentlich ist. Um auch umfeldbezogene Maßnahmen stärker zu fördern, könnte zudem das – in Deutschland bereits seit vielen Jahren etablierte – Programm einer Städtebauförderung, ergänzend zur Wohnbauförderung, interessant sein.

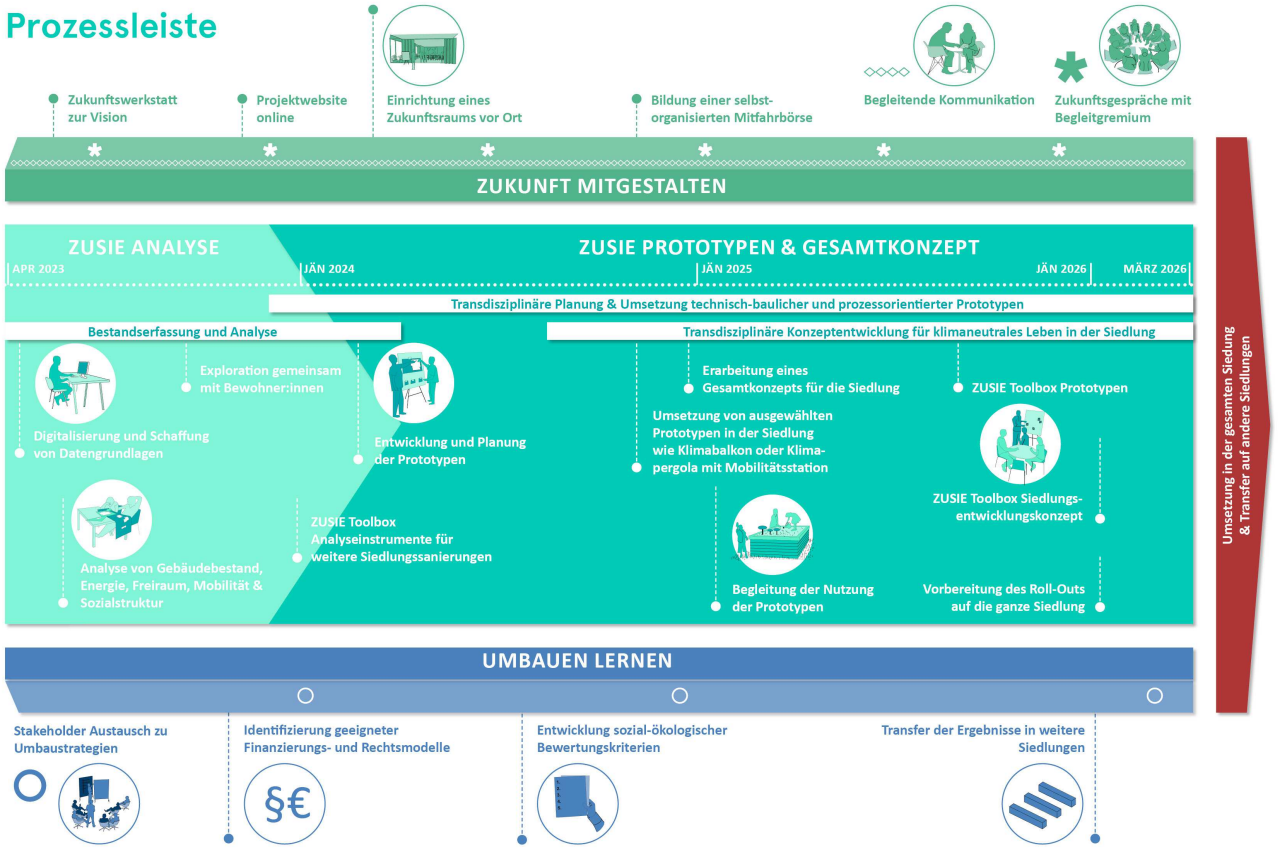

Abb. 11: Prozessdarstellung Smart-Cities-Projekt „ZUSIE – Zukunft Siedlung“ © ZUSIE, Grafik: einszueins

7.4 Multiplizierbarkeit und Skalierbarkeit?

Der vergleichende Blick auf die beiden Projekte und Siedlungen unterstreicht zunächst die Relevanz von spezfischen Entwicklungswegen und Maßnahmen. Gleichzeitig stellt sich sehr wohl die Frage, inwieweit einzelne Elemente auch multiplizierbar oder skalierbar sind. Grundsätzlich haben technische und bauliche Elemente und Lösungen, nachdem sie prototypisch erprobt wurden, das Potenzial, gerade in Siedlungen mit ähnlichen baulichen und städtebaulichen Strukturen auch transferiert und multipliziert zu werden. Auf die konkreten Rahmenbedingungen, artikulierten Bedarfe seitens der Bewohnerinnen, Bewohner und Gemeinden sowie im konkreten Fall geeignete Modelle für Finanzierung, Errichtung und Verwaltung ist allerdings dennoch zu achten. So können – mit Einbeziehung bereits erprobter Elemente – immer wieder

auch ein Stück weit neue, für eine lokale Situation stimmige Maßnahmenbündel entwickelt werden. Nach Möglichkeit unter Einbeziehung und Involvierung der Bewohnerinnen und Bewohner und ihrer Perspektiven.

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User Experiences on the Integration of Non-Motorised Transport in Public Transport Systems: a Case of the Harambee Bus Rapid Transit

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1 ABSTRACT

The transportation industry is the leading contributor to greenhouse gas emissions and there is a need for more sustainable forms of public transportation in cities. Non-motorised transport (NMT) includes walking, cycling, animal drawn transportation, skating and so forth. With an increasing demand of public transportation and convenience, more cities around the world look towards the integration of NMT into public transportation systems. Accessibility, infrastructure, safety and sustainability are four core components when integrating NMT and public transport, however, very little is known around performances of innovative transport systems in meeting the needs of users/commuters. A case study research design using the case of the Harambee bus rapid transit (BRT). The study adopted qualitative and quantitative research approaches. Data collection instruments in the form of survey questionnaires and participant observations were used to gather from commuters. The four core components of accessibility, infrastructure, safety and sustainability were identified. It was found majority of Harambee BRT and NMT trips are work related. Most Harambee BRT users utilise the provided NMT, and the majority of trips start and end in Thembisa. Aspects of accessibility and sustainability of the NMT had positive user experiences. User experiences around safety and infrastructure of the NMT had shortcomings with camera provision, patrolling of guards, a desk to report issues, barriers between road users, water and shelter provision. More urban planning research around the functions and standards of BRT and NMT users need to be carried out and a model needs to be designed using these results to assist planners and policy makers when implementing similar projects.

Keywords: public transport, non-motorised transport, accessibility, safety, infrastructure

2 INTRODUCTION

The need for sustainable public transport development is constantly growing. Sustainable transportation lessens environmental impacts and ensures that future generations are able to fulfil their own needs. One of the most important sustainable modes of transport is non-motorised transport (NMT). NMT will have to adopted in South Africa due to the increase in population (Okoro and Lawani 2022). According to Salleh, Rahmat and Ismail (2014: 290), in order to influence a modal shift to NMT, the following five areas of improvement are required, “improved convenience and comfort for NMT users; improved transport options; building up attractive and liveable communities; improved basic mobility for nondrivers; and improved land-use efficiency”. Studies show the implementation of NMT and technology in transport has proven to not only improve economic development but also increases mobility (Okoro and Lawani 2022). Ekurhuleni has implemented a bus rapid transit (BRT) system which also has NMT infrastructure to connect users to various BRT stations.

Therefore, the paper starts of by identifying the different facets of NMT in PT. It then goes on to investigate South Africa’s Harambee BRT and NMT user experiences and behaviours. Finally, it draws on these experiences to state the implications on urban planning.

3 LITERATURE REVIEW

3.1 Accessibility

The traditional definition of accessibility according to Orellana et al. (2020: 3) is, “the access level of people to jobs and services given their spatial location and transportation options”. This understanding of access referred to urban and transportation planning. The four components that this definition encompassed were:

land-use, transportation, temporal components, and individual characteristics. For the past few decades, these components have influenced accessibility models. This view of accessibility somehow overlooks or excludes certain groups because of physical, economic and social conditions (Orellana et al. 2020: 3). The inclusive cities paradigm proposes universal access for all which means that every person should have a right to go wherever they want whenever they want to. It is about cities allowing people to live freely through walking, cycling or using a wheelchair. Universal access in cities is accepted globally in order to include people with disabilities. There are many theoretical studies covering the paradigm, however, though universal access designs might not add much to the total cost of projects, there is still a lack of practical implementation in urban and architectural designs (Orellana et al. 2020: 3).

3.2 Infrastructure

NMT infrastructure is one of the most integral components of an efficient transport system which leads to mobility and accessibility to everyday opportunities (Okoro and Lawani 2022: 68). Besides this, the provision and the upgrading of the NMT infrastructure comes along with many benefits such as the reduction in healthcare costs, the prevention of numerous diseases, improved wellbeing and increased life expectancy. This leads one to believe that the NMT infrastructure is an investment. Okoro and Lawani (2022: 68) go on to state that a sustainable NMT infrastructure has many environmental benefits which lessen the impacts of transport developments and provide a cleaner and healthier environment for an improved quality of life. Traditionally, key performance indicators for road transport infrastructure were determined using technical measures such as structural integrity, visual appearance and functional performance. Okoro and Lawani (2022: 68) believe that NMT users should be included in surveys. NMT infrastructure is considered sustainable when it benefits the functionality of the city, improves environmental impacts, contributes to the improved health of users, the enhancement of infrastructure, increased traffic calming measures and the reduction of related injuries and accidents (Okoro and Lawani 2022: 68).

Pedestrians find the journey of a trip just as important as the destination which is why it is imperative that an integrated pedestrian network is created. This should be attractive enough for pedestrians so that they use NMT to either access these pedestrian facilities or use them as a point or link connecting them to their destination. Cyclist facilities must provide smooth trips which refers to a dedicated space for cyclists at a safe distance away from motorists and pedestrians. The trip should have few stops, and barriers and any other hinderances need to be minimised to save time, effort and energy when cycling (Kamundu 2019: 29-30). Amenities should be provided to make pedestrian and cyclist trips a little easier and comfortable. These include seating, shelter, recreational open spaces, water provision (taps/fountains) and even signage (Kamundu 2019: 29-30).

3.3 Safety

The two aspects that can refer to safe NMT are protection from crime and being protected from accidents or injury. Crime is one of the main deterrents of NMT use, because private motorised vehicles and public transport are seen as more safe and secure modes of transportation. It is not the direct responsibility of planners to solve the issue of crime in relation to NMT, however, these solutions are required for the effective usage of NMT both during the day and specifically at night. Though planners can use various design principles to promote overall safety (Becker 2011: 10). NMT users, specifically pedestrians, are the most vulnerable in motor vehicle accidents due to their lack of protection (Venter 2017: 643). NMT users are also at risk of injury when private vehicle users approach at higher speeds, motorists under the influence of alcohol, and poor bicycle conditions. The issue of high speeds can be solved by enforcing a speed limit when approaching NMT users, strict laws, education and consistent controls in place to deal with drivers under the influence of alcohol. Poor bicycle conditions can be dealt with through bicycle users wearing reflector vests where lights are unavailable (Becker 2011: 9-10).

3.4 Sustainability

The traditional definition of sustainability according to White (2013: 213) is “development which meets the needs of the present without compromising the ability of future generations to meet their own needs”. This definition’s main focus is on health and community (Figure 14). It can also be noted that this is a form of “negative sustainability”, in that it seeks to keep the system going through the reduction of harmful actions (James and Magee 2016: 3). This form of sustainability just seeks to reduce negative effects of previous

development or human practice that might affect the future. James and Magee (2016: 3) define "positive sustainability" as, "practices and meanings of human engagement that make for life worlds that project and support ongoing natural and social flourishing".

4 METHODOLOGY

Survey research participants were those that utilise the Harambee BRT and were chosen at random. Convenience sampling was used and data collection occurred along the route of the four different terminals as well as inside Harambee BRT buses and various stops along the Harambee BRT which were the Thembisa Hospital, Diesel, OR Tambo International Airport (ORTIA) and Airports Company of South Africa (ACSA) Super South. The sample size was 50 participants per day over four days at each terminal respectively. This study utilised survey questionnaire sheets which were administered face-to-face. The questionnaires consisted of closed-ended and multiple-choice questions. The questions pertained to user experiences of the Harambee BRT and NMT. The researcher, while conducting the survey research became an observer as a participant as terminals were not as busy. Research was then conducted at terminals and along the routes of the Harambee BRT in order to observe the entire experience. The researcher was able to interact with Harambee BRT users and get valuable information and insights that were not necessarily on survey questionnaires. Cross tabulations were used to analyse survey data. The data quantified responses from Harambee BRT users and provided accurate statistics on how feasible the provision of NMT actually was with the Harambee BRT.

Participant observations utilised random, convenience sampling. Participants were users of the Harambee BRT and were chosen at random and could participant if they were willing to be observed. Three participants per location, per day (Thembisa Hospital, ORTIA, ACSA Super South and Diesel) were chosen at random. There were a total of 12 participants who were observed. A thematic analysis approach was applied to the data obtained from participant observations and stakeholder interviews. Themes around participant observations were used to support and contrast user experiences relating to accessibility, infrastructure, safety and sustainability.

5 RESULTS

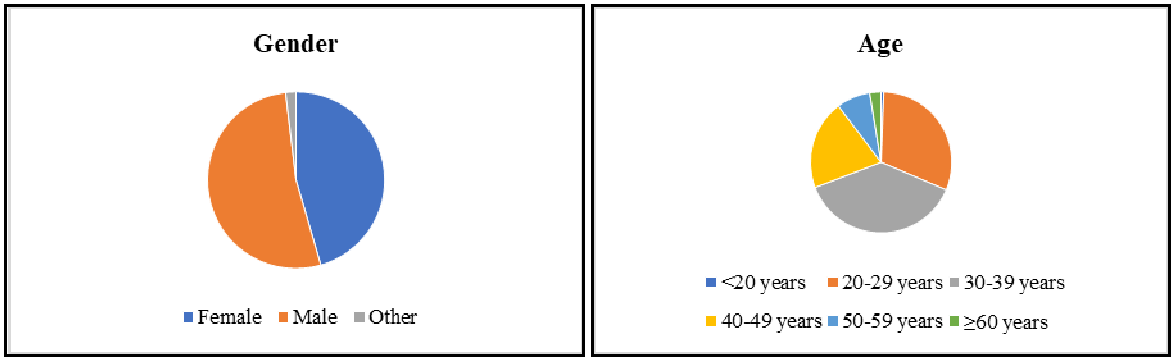
5.1 Introduction

The results explore user experiences based on a survey analysis, and participant observations then act as a support for user experiences. The discussion ties the overall results into one another and draws on previous studies of this nature to make valuable conclusions.

5.2 Surveys

5.2.1 Personal data

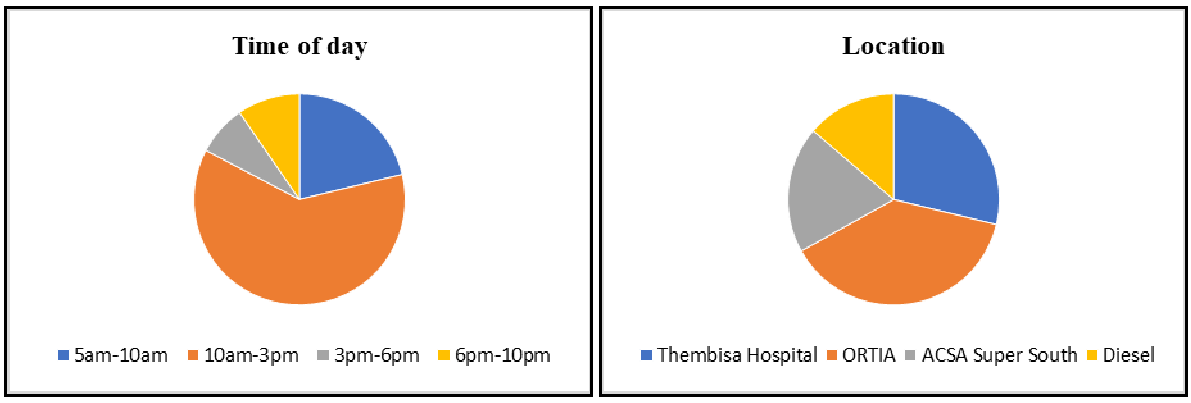
There were a total of 156 participants of which there were; 71 (45,5%) females, 82 (52,6%) males and 3 (1,9%) participants who identified as other (Graph 1).



Graph 1 (left): Gender of participants. Graph 2 (right): Age of participants

Of the total 156 participants, there was 1 (0,6%) participant less than 20 years; 48 (30,8%) participants 20 to 29 years; 59 (37,8%) participants 30 to 39 years; 32 (20,5%) participants 40 to 49 years; 12 (7,7%) participants 50 to 59 years and 4 (2,6%) participants 60 years and older (Graph 2).

The time of day that each survey took place was 33 (21,2%) surveys between 5am-10am; 96 (61,5%) surveys between 10am-3pm; 12 (7,7%) surveys between 3pm-6pm; and 15 (9,6%) surveys between 6pm-10pm (Graph 3).



Graph 3 (left): Time of day. Graph 4 (right): Location

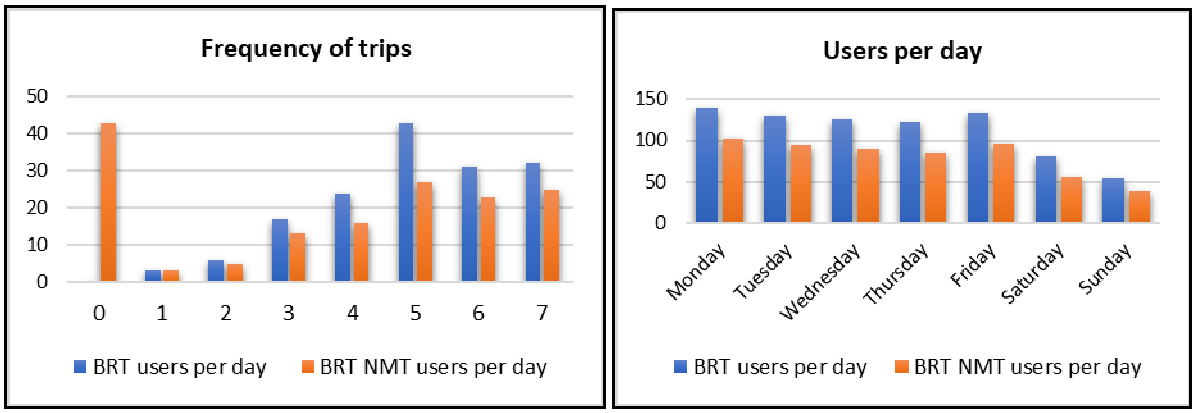
The locations where each survey took place were 42 (29,6%) surveys at Thembisa Hospital; 61 (39,1%) surveys at ORTIA; 31 (19,9%) surveys at ACSA Super South and 22 (14,1%) at Diesel (Graph 4).

5.2.2 Harambee BRT and NMT statistics

All participants are users of the Harambee BRT. It was found that of the 156 BRT users, there were 112 (71,8%) who utilised the provided NMT, and 44 (28,2%) BRT users did not use the provided NMT.

Frequency of Harambee BRT and NMT trips per week

Of the 156 participants that use the Harambee BRT, there were 3 (1,9%) participants which use the BRT once a week; 6 (3,8%) participants which use the BRT twice a week; 17 (10,9%) participants which use the BRT three times a week; 24 (15,4%) participants which use the BRT 4 times a week; 43 (27,6%) participants which use the BRT 5 times a week; 31 (19,9%) participants use the BRT 6 times a week and 32 (20,5%) participants who used the BRT 7 times a week (Graph 5).



Graph 5 (left): Number of days a week Harambee BRT and NMT used. Graph 6 (right): Days of the week that the Harambee BRT and NMT are taken.

Of the 155 responses, 43 (27,7%) participants use the Harambee BRT NMT 0 days in the week; 3 (1,9%) use the NMT 1 day a week; 5 (3,2%) use the NMT 2 days a week; 13 (8,4%) use the NMT 3 days a week; 16 (10,3%) use the NMT 4 days a week; 27 (17,4%) use the NMT 5 days a week; 23 (14,8%) use the NMT 6 days a week and 25 (16,1%) use the NMT every day in the week (Graph 5).

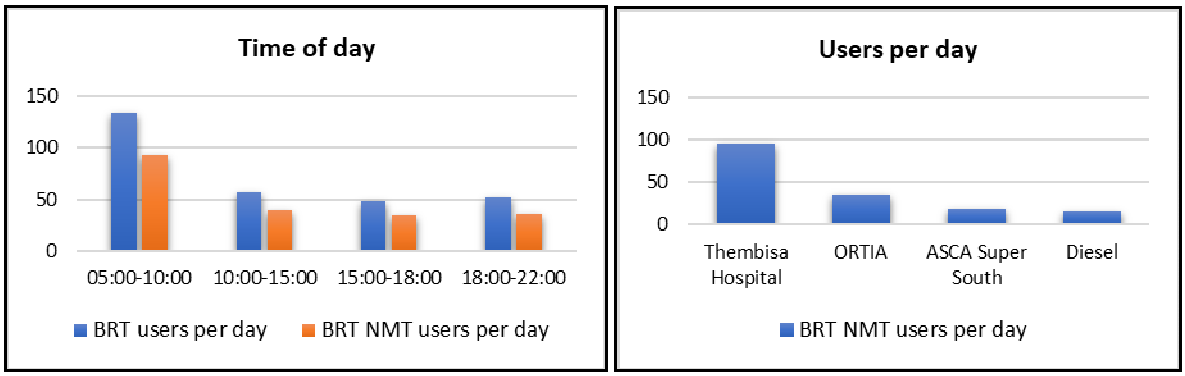
Days of the week that the Harambee BRT and NMT are taken

Of the 156 participants that use the Harambee BRT, there were; 140 (89,7%) participants which use the BRT on a Monday; 131 (84%) participants which use the BRT on a Tuesday, 126 (80,8%) participants which use the BRT on a Wednesday; 123 (78,8%) of participants which use the BRT on a Thursday; 133 (85,3%) participants which use the BRT on a Friday; 80 (51,3%) participants which use the BRT on a Saturday and 54 (346%) participants which use the BRT on a Sunday (Graph 6).

Of the 112 participants that use the Harambee BRT NMT, there were 103 (92%) participants which use the NMT on a Monday; 95 (84,4%) participants which use the NMT on a Tuesday; 90 (80,4%) participants which use the NMT on a Wednesday; 85 (75,9%) participants which use the NMT on a Thursday; 96 (85,7%) participants which use the NMT on a Friday; 56 (50%) participants which use the NMT on a Saturday and 39 (34,8%) participants which use the NMT on a Sunday (Graph 6).

Time of day that Harambee BRT and NMT are used

Of the 156 participants that use the Harambee BRT; there were 134 (85,9%) participants who use the BRT between 05:00-10:00; 57 (36,5%) participants use the BRT between 10:00-15:00; 48 (30,8%) participants use the BRT between 15:00-18:00 and 52 (33,3%) participants use the BRT between 18:00-22:00 (Graph 7).



Graph 7 (left): Time of day that Harambee BRT and NMT are used. Graph 8 (right): Location of NMT use.

Of the 112 participants that use the Harambee BRT NMT; there were 93 (83%) participants who use the NMT between 05:00-10:00; 40 (35,7%) participants use the NMT between 10:00-15:00; 35 (31,3%) participants use the NMT between 15:00-18:00 and 36 (32,1%) participants use the NMT between 18:00-22:00 (Graph 7).

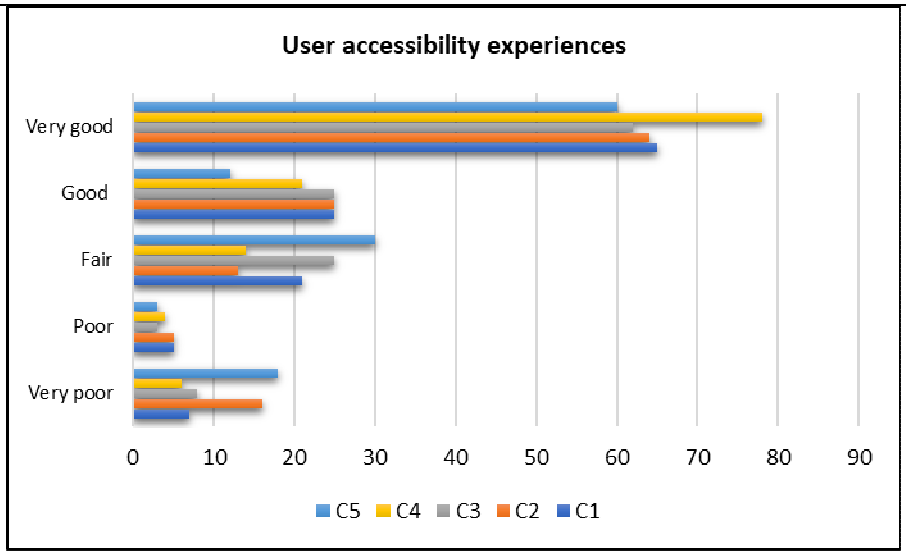
Location of NMT use

The locations of users per day were 96 users at Thembisa Hospital; 35 users at ORTIA; 19 users at ACSA Super South and 15 users at Diesel (Graph 8).

5.2.3 Accessibility of NMT

Participants were asked to rate how they felt about the purpose of their NMT trips (Graph 9: C1) in terms of whether or not the NMT was taking them to work, malls, hubs, etc. (somewhere of purpose). Of the 123 participants; 7 (5,7%) find the purpose of Harambee BRT NMT trips to be very poor; 5 (4,1%) find it poor; 21 (17,1%) find it fair; 25 (20,3%) find it good, and 65 (52,8%) find it very good. The provisions of which enable commuters to utilise the Harambee BRT NMT (ramps, signs, etc) were surveyed. Of the 123 participants, 16 (13%) find the provisions which enable all to use the Harambee BRT NMT very poor; 5 (4,1%) find it poor; 13 (10,6%) find it fair; 25 (20,3%) find it good, and 64 (52%) find it very good (Graph 12: C2). Participants feelings towards the fluidity of the Harambee BRT NMT in terms of the number of breaks in the NMT and whether or not they had to utilise other modes of transport were recorded (Graph 12: C3). Of the 123 participants, 8 (6,5%) find the overall fluidity of the Harambee BRT NMT to be very poor; 3 (2,4%) find it poor; 25 (20,3%) find it fair; 25 (20,3%) find it good; and 62 (50,4%) find it very good.

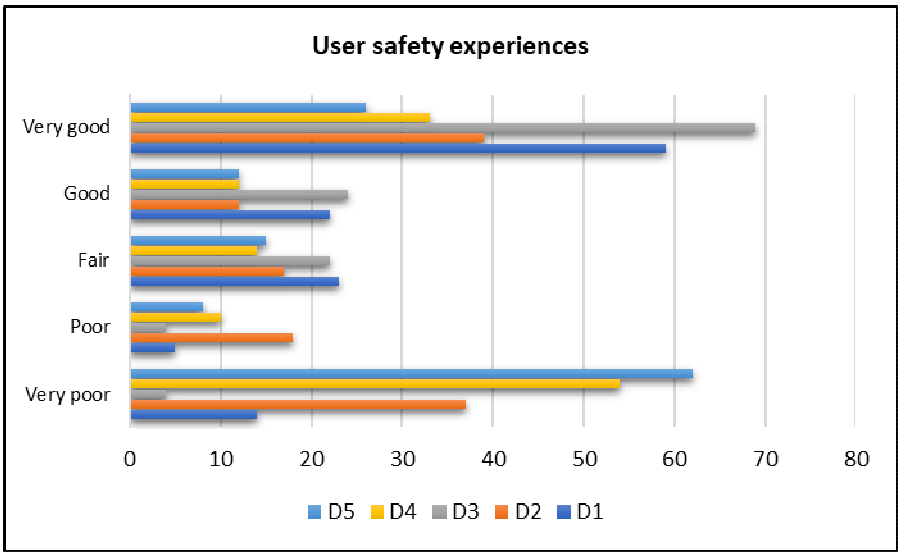
The Harambee BRT NMTs pick-up and drop-off points ease of accessibility were surveyed among users (Graph 9: C4) and of the 123 participants 6 (4,9%) find the pick-up and drop-off points accessibility of the Harambee BRT NMT very poor; 4 (3,3%) find it poor; 14 (11,4%) find it fair; 21 (17,1%) find it good and 78 (63,4%) find it very good. Participants shared their experiences of Harambee BRT NMT trip lengths with short trips being positive and long trips being negative (Graph 12: C5). Of the 123 participants; 18 (14,6%) find the Harambee BRT NMT trip lengths very poor; 3 (2,4%) find it poor; 30 (24,4%) find it fair; 12 (9,8%) find it good and 60 (48,8%) find it very good.



Graph 9: User accessibility experiences

5.2.4 Safety of NMT

The amount of lighting along the Harambee BRT NMT was surveyed among participants (Graph 10: D1) and of the 123 participants; 14 (11,4%) find the lighting along the Harambee BRT NMT very poor; 5 (4,1%) find it poor; 23 (18,7%) find it fair; 22 (17,9%) find it good and 59 (48%) find it very good. Participants' experiences in terms of the patrolling of security guards; whether it be on foot or in patrol vehicles at Harambee BRT NMT was recorded (Graph 13: D2). Of the 123 participants; 37 (30,1%) find patrolling of security along the Harambee BRT NMT very poor; 18 (14,6%) find it poor; 17 (13,8%) find it fair; 12 (9,8%) find it good and 39 (31;7%) find it very good. The overall layout of the Harambee BRT NMT in terms of whether corners are visible, and the layout is practical was measured (Graph 13: 3). Of the 123 participants; 4 (3,3%) find the overall layout of the Harambee BRT NMT very poor; 4 (3,3%) find it poor; 22 (17,9%) find it fair; 24 (19,5%) find it good and 69 (56,1%) find it very good.

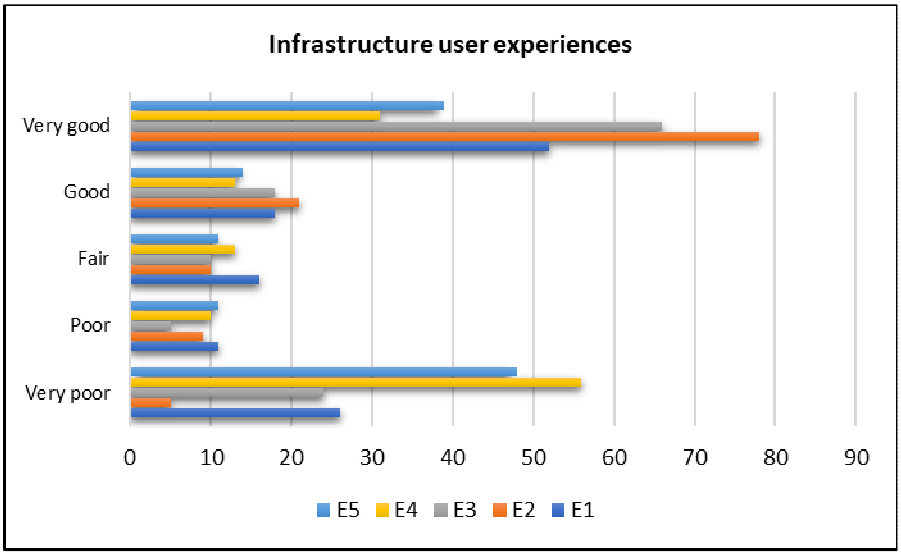


Graph 10: User safety experiences

The prevalence of self-help desks available (Graph 10: D4) to Harambee BRT NMT users reported that; of the 123 participants; 54 (43,9%) find the availability of self-help desks at the Harambee BRT NMT very poor; 10 (8,1%) find it poor; 14 (11,4%) find it fair; 12 (9,8%) find it good and 33 (26,8%) find it very good. Harambee BRT NMT users expressed their experiences on the number of cameras provided along the NMT route (Graph 13: D5). Of the 123 participants; 62 (50,4%) find the number of cameras provided along the Harambee BRT NMT very poor; 8 (6,5%) find it poor; 15 (12,2%) find it fair; 12 (9,8%) find it good and 26 (21,1%) find it very good.

5.2.5 Infrastructure of NMT

In terms of the number and quality of seating and rest stops provided at the Harambee BRT NMT (Graph 11: E1); it was reported of the 123 participants that 26 (21,1%) find the number and quality of seating and rest stops at the Harambee BRT NMT very poor; 11 (8,9%) find it poor; 16 (13%) find it fair; 18 (14,6%) find it good and 52 (42,3%) find it very good. Participants were asked about the materials used on the Harambee BRT NMT paving and whether or not it is compatible for NMT use (Graph 14: E2). Of the 123 participants; 5 (4,1%) find it very poor; 9 (7,3%) find it poor; 10 (8,1%) find it fair; 21 (17,1%) find it good and 78 (63,4%) find it very good. The quality of the barrier separating motorists and Harambee BRT NMT users was investigated (Graph 14: E3). Of the 123 participants; 24 (19,5%) find the quality of the Harambee BRT NMT barrier very poor; 5 (4,1%) find it poor; 10 (8,1%) find it fair; 18 (14,6%) find it good and 66 (53,7%) find it very good.



Graph 11: User infrastructure experiences

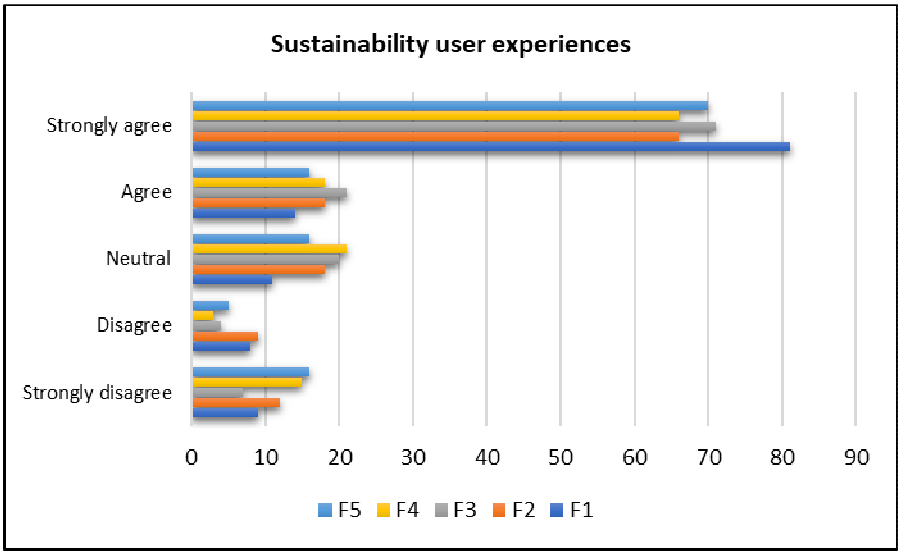
The provision of water at Harambee BRT NMT rest stops was surveyed and participants expressed their experiences (Graph 11: E4). Of the 123 participants; 56 (45,5%) find the provision of water at Harambee BRT NMT rest stops very poor; 10 (8,1%) find it poor; 13 (10,6%) find it fair; 13 (10,6%) find it good and 31 (25,2%) find it very good. Participants were surveyed on the provision of shelter along the Harambee BRT NMT (Graph 14: D5) and it was reported, of the 123 participants; 48 (39%) find the provision of shelter along the Harambee BRT NMT very poor; 11 (8,9%) find it poor;11 (8,9%) find it fair; 14 (11,4%) find it good and 39 (31,7%) find it very good.

5.2.6 Sustainability of NMT

The monetary benefits from using the Harambee BRT NMT were investigated (Graph 12: F1). Of the 123 participants; 9 (7,3%) participants strongly disagree with receiving monetary benefits from using the Harambee BRT NMT; 8 (6,5%) participants disagree;11 (8,9%) participants are neutral;14 (11,4%) participants agree, and 81 (65,9%) participants disagree. Participants were surveyed on the health benefits of using the Harambee BRT NMT (Graph 15: F2). Of the 123 participants; 12 (9,8%) participants strongly disagree with receiving health benefits through the use of the Harambee BRT NMT; 9 (7,3%) participants disagree; 18 (14,6%) participants are neutral; 18 (14,6%) participants agree, and 66 (53,7%) participants disagree. In terms of the environmental benefits of using the Harambee BRT NMT, it was reported, of the 123 participants; 7 (5,7%) participants strongly disagree with there being environmental benefits through the use of the Harambee BRT NMT; 4 (3,3%) participants disagree; 20 (16,3%) participants are neutral; 21 (17,1%) participants agree, and 71 (57,7%) participants disagree.

Participants were asked whether there would be a reduction in motorised vehicle usage through the use of the Harambee BRT NMT (Graph 12: F4). Of the 123 participants; 15 (12,2%) participants strongly disagree with reduction in motorised vehicle usage through the use of the Harambee BRT NMT; 3 (2,4%) participants disagree; 21 (17,1%) participants are neutral; 18 (14,6%) participants agree, and 66 (53,7%) participants strongly agree. Participants were asked to rate how they felt about the Harambee BRT NMT use aiding in

climate change mitigation and of the 123 participants; 16 (13%) participants strongly disagree that the Harambee BRT NMT use aids in climate change mitigation; 5 (4,1%) participants disagree; 16 (13%) participants are neutral; 16 (13%) participants agree, and 70 (56,9%) participants disagree.



Graph 12: User sustainability experiences (Source: Author 2022)

5.3 Participant Observations

5.3.1 Participant details

There were 12 participants who were observed, 3 at Thembisa Hospital, 3 at ORTIA, 3 at ACSA Super South and 3 at Diesel.

The gender of the participants was chosen at random, 6 females and 6 males.

The age distribution of participants was between 20-29 years, 5 between 30-39 years, 4 between 40-49 years and 1 participant over the age of 60 years.

The time of day that participants were observed was, 3 between 05:00-10:00; 3 between 10:00-15:00; and 6 between 15:00-18:00. The 3 participants between 05:00-10:00; and 3 between 10:00-15:00 were observed from Thembisa Hospital and ORTIA respectively as the Harambee BRT runs more frequently the entire day to and from both locations, whereas the 6 participants between 15:00-18:00 were observed from ACSA Super South and Diesel because the Harambee BRT only runs through these locations in the morning and afternoon.

5.3.2 Thembisa Hospital

Purpose of trip: All 3 participants were using the BRT to get to different locations, while 2 participants were using the BRT from Thembisa Hospital to get to work (ORTIA and Alex Shopping Centre) and mentioned that they only use the BRT for work purposes. The 1 participant uses the BRT.

Safety: Out of the 3 participants, 2 mention the safety of the NMT, both of these think that there is sufficient lighting, however, only 1 finds that patrolling of security is frequent.

Harambee BRT: 1 participant states that there is not access to stations (stations are closed) and 1 gets a lift home after using the BRT so this participant is not aware of whether or not the stations are inaccessible.

Harambee BRT NMT: 1 participant uses the NMT for health reasons, 2 use the NMT because it is free, and 1 participant uses the NMT because they are elderly and the paving used on the NMT lane is easy on the participant to walk on.

Payment: 2 participants use the Ekucard because it is cashless, however, 1 participant forgets to check the balance on their Ekucard and 1 just buys tickets as the concept of the Ekucard is difficult.

5.3.3 ORTIA

Purpose: All 3 participants were leaving work (ORTIA) to go home, 1 only uses the Harambee BRT for work purposes, 1 only uses the NMT when using the Harambee BRT and 1 only uses the NMT sometimes as this participant has a permanent leg injury.

Safety: All 3 participants feel that the NMT is safe and has sufficient lighting and patrolling, however, 1 participant only feels unsafe when cars try to use the NMT lane.

Harambee BRT: 1 participant uses the Harambee BRT because it is always on time and buses frequent the route/stop, 1 uses the Harambee BRT because it is affordable (cheap) and 1 makes mention that they have not used the Harambee BRT rest stops (located at stations).

Harambee BRT NMT: 2 participants use the NMT for health reasons, 1 mentions that they have to still take a taxi home after using the NMT, while another lives close by, and the NMT takes the participant straight home, 1 participant notes that the NMT paving is good/suitable.

Payment: 2 participants only use the Ekucard because going cashless makes them feel safe and 1 uses the Ekucard but says it is hard to remember to load money onto it, so the participant resorts to buying tickets.

5.3.4 ACSA Super South

Purpose: All 3 participants use the Harambee BRT NMT for work from Emperors Palace to home. All 3 state that they only use the Harambee BRT for work purposes only.

Safety: All 3 participants feel that there is not enough lighting and 2 state that they do not see patrol vehicles.

Harambee BRT: 1 participant uses the Harambee BRT because it is cheap, 1 reports that the Harambee BRT rest stops are always closed and 1 mentions a lack of seating. 2 were anxious waiting for the bus to arrive because of the lack of lighting and the fact that buses are not as frequent and 1 does not mind waiting for the Harambee BRT because the participant has a friend to wait with for the bus.

Harambee BRT NMT: 2 participants still need a lift home after using the Harambee BRT NMT because they live quite far away; 1 uses the NMT for convenience and 1 uses the NMT because it is free and helps the environment.

Payment: All 3 participants use the Ekucard to avoid waiting in lines during the morning rush to buy tickets.

5.3.5 Diesel

Purpose: All 3 participants use the Harambee BRT for work and were going from a trucking company, foundry and logistics company in Isando.

Safety: All 3 participants feel that there is not enough lighting, 2 note that there are no patrol vehicles and 1 has heard of a mugging and does not see many other women in the area which is why the participant does not use the NMT.

Harambee BRT: 1 participant uses the BRT because it is reliable and on time, 1 feels that the Harambee BRT is cheaper than other modes of transport, however, 1 notes that using a taxi is cheaper and drops the participant closer to home. 1 needs a lift from the Harambee BRT stop because the participant lives too far away from the nearest stop. 1 participant notes that the Harambee BRT stops do not have shelters, while 2 do not mind waiting for the Harambee BRT; however, 2 participants fear getting mugged waiting for the BRT when it gets later/darker.

Harambee BRT NMT: 2 participants feel safe enough to use the NMT, 1 thinks that the NMT is convenient for the participant's taxi to fetch them from the stop. 1 does not use the NMT because the participant heard about a mugging, so the participant gets a lift home from the Harambee BRT station.

Payment: 2 participants use their Ekucards because they feel safer not buying tickets and carrying money to buy tickets, while 1 prefers to buy tickets whenever the participant requires it as they are not a frequent user.

6 DISCUSSION

The results from both the user experiences and participant observations are further analysed and conclusions drawn below. Each theme is further broken down and discussed with the aid of contrasting or similar case studies.

6.1 Participant demographics

The gender split of participants was reasonable with their just being 11 more males (82) than females (71) and 3 participants who identify as other. Due to there being a negligible difference in the numbers, results obtained represent all genders fairly. It can be deduced that the 20-49 years' age bracket use the Harambee BRT (participant observations support this with majority of participants using the BRT for work purposes), with a sizable number of users over 50 years (10,3%) and the lowest number coming from the under 20 years' age bracket. The majority of surveys took place between 5am-3pm, while the least number of surveys were done between 3pm-6pm. The aim of the study was to survey around 50 participants per location, however, ORTIA and Thembisa Hospital saw the largest number of participants (103) and ACSA Super South and Diesel saw the lowest number (53).

6.2 Harambee BRT and NMT use

There were 156 Harambee BRT users surveyed. Of this, it was found that 112 BRT users also use the Harambee BRT NMT and only 44 do not. The highest number of days in a week that the Harambee BRT is used ranges from 5-7 days and the lowest ranges from 1-4 days. The highest number of days in a week that the Harambee BRT NMT is used is 0 days, then ranging from 5-7 days and the lowest ranges from 1-4. Both the Harambee BRT and NMT see the highest number of users between Monday-Friday, with the lowest number being over the weekend which is Saturday and Sunday. Participant observations corroborate with results, as most trips are work related (majority Monday-Friday). The reason for majority of trips being work related could be that majority of students attend universities in neighbouring municipalities (City of Tswane and City of Johannesburg) as Ekurhuleni is yet to open its first university which is still under construction. The highest number of Harambee BRT and NMT trips occur between 5am-10am, while, 10am-10pm has around the same low number of users. The highest number of participants use the NMT in Thembisa, followed by ORTIA, ACSA Super South and Diesel. Participant observations suggest that the majority of trips start and end in Thembisa which supports the results obtained.

6.3 Accessibility

User experiences indicate that the majority find the overall accessibility of the NMT to be 'very good' in terms of the NMT providing purpose trips, ramps and other provisions to accommodate all users, such as the fluidity of the NMT, accessible pick-up and drop-off points and trip length. Participant observations also corroborate with this response in that a user over the age of 65 years, states that the paving used in NMT walkways is much easier to walk on. In support of this finding, a study in Zaragoza, Spain, states that the elderly (>65 years old) are less likely to walk as much as those younger (<65 years old) which excludes older users. However, in the case of the Harambee BRT NMT, paving plays an important role in increased NMT use by older users (Arranz-López et al. 2019: 644-649).

6.4 Safety

User experiences were quite mixed in terms of safety, with lighting and the overall layout of the Harambee BRT NMT appearing to be 'very good'. However, the patrolling of security was almost split between two extremes of 'very good' and 'very poor'. User experiences were 'very poor' for the provision of self-help desks to report issues and cameras at multiple locations of the NMT. Observations indicate that the aspect of safety is different depending on the areas. For example, Thembisa Hospital and ORTIA seem to have no issues with safety, however, at ACSA Super South and Diesel, all participants raised issues of safety concerns. A study undertaken in China found that crime affects the number of users willing to use NMT, but China then adopted the system of guanxi to try and remedy the situation (Day 2016: 313-315).

6.5 Infrastructure

User experiences seem to indicate that the seating and rest stops provided, paving and barriers separating the NMT from the roadway are 'very good'. The majority of users find the water provision at rest stops and shelter provision 'very poor'. However, a considerable number feel that the seating and rest stops provided are 'very poor' and shelter provision 'very good'. Users expressed the opinion that they have not yet been able to access seating and shelter at Harambee BRT stations as they remain closed and under construction. This result is supported by two studies, one in Rajkot, Vizag and one in Minneapolis, United States of America both conclude that there is increased NMT use when there is an improvement in NMT

infrastructure (Tiwari, et al. 2016: 289-290; Hankey et al. 2012: 315). Participants do find the usage of Ekucards to make using BRT services seamless going straight from using the NMT into buses without having to wait for tickets.

6.6 Sustainability

User experiences found that participants 'strongly agree' with the monetary benefits from using the NMT, health benefits from using the NMT, environmental benefits from using the NMT, reduction in the use of private motorised transport and climate change mitigation. Participant observations corroborate survey results, as the most common themes around the use of the Harambee BRT NMT is because it is free, and participants feel that walking/cycling makes them healthier. A case study was made of Italian cities during the COVID-19 pandemic. This found that allocating space to walking and cycling (sustainable mobility) with social distancing protocols led to the promotion of active lifestyles which proved to be very successful and changed the way urban spaces are planned (Barbarossa 2020: 17).

7 CONCLUSION

Given the fact that majority of BRT users make use of the provided NMT, it can be deduced that planners are to incorporate NMT into their public transport plans not just exclusively to BRT plans. It proves that integrated public transport networks can work if executed strategically and considering user experiences of a working project. Urban planners need to address certain aspects around safety (camera provision, patrolling and help desks) and infrastructure (barriers protecting NMT users from motor vehicles and shelter provision) when implementing such projects. More urban planning research around the expectations of BRT and NMT users need to be carried out and a model needs to be designed using these results to assist planners and policy makers when implementing similar projects.

It can be concluded that a lot of the Harambee BRT and NMT trips are work related. Most Harambee BRT users utilise the provided NMT, and the majority of trips start and end in Thembisa. When looking at the accessibility aspect of the Harambee BRT NMT, users were very happy with the provisions in place to make the NMT accessible to all. They were, however, pleased with some aspects such as the amount of lighting provided and layout of the NMT, but displeased with aspects such as camera provision, patrolling of guards and a desk to report issues. Users found infrastructure such as seating and paving along the NMT to be excellent, however, some found the barriers protecting them from road users, water and shelter provision were not up to standard. Harambee BRT NMT users found the aspect of sustainability to be positive when using the NMT. Further research exploring the urban fabric and trip purposes could provide valuable insight into travel behaviour of participants.

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User Preferences for Mobility as a Service (MaaS) Implementation in Germany

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1 ABSTRACT

Mobility as a service is an innovative concept that has become important due to the vast demand for mobility options in smart cities and cities focused on sustainability. Many studies have been researched on smart mobility options, and the important element is mobility as a service. Many authors concluded that user acceptance is the key feature of MaaS. However, there is a research gap in the criteria evaluated by the users before accepting MaaS hence the below research questions were developed for this study.

Keywords: MaaS, Mobility as a Service, Smart Mobility, user preferences, Smart City

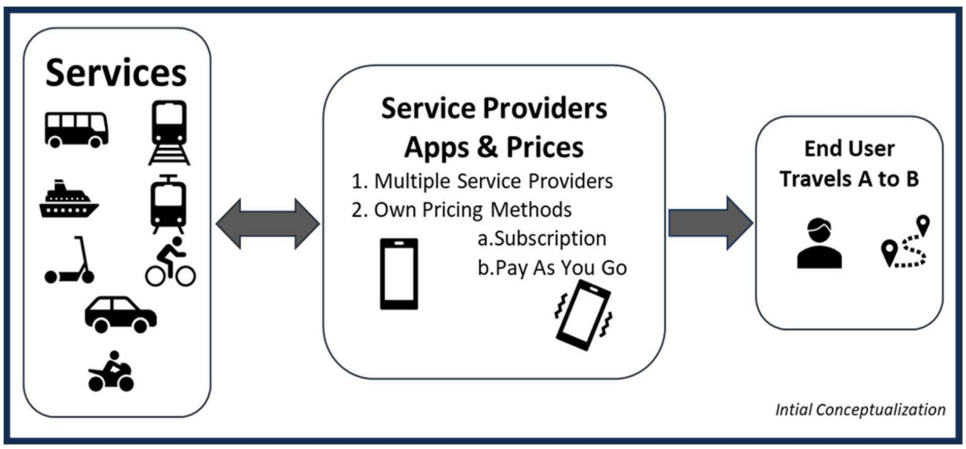
2 INTRODUCTION

The increasing demand for mobility and digitalization has boomed new mobility services. MaaS is known to be a key solution to limiting the ownership of private cars and promoting intermodal various transport options with the convenience of planning, booking, and payment via a single platform (Smith et al. 2019). Practical experience with this service is evident as some of the cities around the world have opted for MaaS for the transport sector. Even though the foundation of smart mobility MaaS The birth of existed in the late 1990s the birth of MaaS word was introduced by a thesis student in Finland, Sonja Heikkila in 2014 incorporating digital service and mobility ecosystem. The supervisor, Sampo Hietanen incorporated MaaS Global in 2015 and introduced the first ever MaaS platform “Whim app” in Helsinki, Finland (Citie-today, 2021).

Mobility as a service is deemed as an advanced ecosystem that leads to disruptive changes in the transport system (Alyavina 2022). This concept does not provide access to individual transport services but offers transport services when it is needed (Enoch 2023).

Germany located in the heart of Europe, has a vast range of mobility hubs that cover land, air, and water transport modes hence research on MaaS is an interesting phenomenon to understand the user acceptance for a single platform that provides all forms of transport options. Although the public and shared transport modes have a significant share in the transport system, Private car ownership was 48m in 2020 (ACEA, 2022). A study concluded that private vehicle owners have underestimated the cost of using a private mode of transport providing these facts will influence users to move to sustainable transport modes and reduce carbon emissions (Andor et al, 2020).

Annual growth of 11.95% is estimated for shared mobility from 2020-2026 and potential shared mobility users of 63.4m by 2026. The cost has been the main factor in opting for private or public and shared mobility modes (Skedgo, 2022).



This research focuses on user preferences when accepting MaaS in Germany. The smart city index analyzes all German cities in five categories. Administration, society, transport, IT infrastructure, and energy/environment. Hamburg has topped the smart city index for three consecutive years, 2019-2021. By 2030 Hamburg targets to achieve goals set in “ITS strategy” in 2016 (a-tour, 2021).

The coalition agreement signed in 2021 by the partners of the new government focuses on green and zero carbon emissions for the German economy. The highlights of the transport policy are a significant investment in rail transport over the road an increase in the rail freight share by 25% by 2030 and a 100% increase in existing passenger transport, 75% of the rail network to be electrified by 2030, support digital mobility services, innovative mobility solutions and promote long term strategies for autonomous and linked public transport, etc. (Changing Transport, 2021).

3 LITERATURE REVIEW

3.1 Smart mobility

Smart mobility is defined as an expert system that provides access to mobility services via a combined platform by Dorchery et al. (2018). These platforms enable the community to forecast the transport demand accurately also the platform provides details of prevailing smart infrastructure. As explained by Salvia et al. (2016). Sustainability and safety are the two main aspects that fulfill the smart mobility system. The mobility system should be integrated with intelligent systems which allows the users to get traffic information in real-time. The need for a sharing economy has driven many commercial sectors which has offered new business opportunities and scraped traditional sectors (Acquier et al. 2019). Mobility markets that follow a sharing economic model have been driven in many urban and rural cities across the world (Hamari et al., 2016; Yin et al., 2018). The first shared electronic scooters are in business use in Finland and drones are used in Finland to identify the need for package transport. Bike and Scooter-sharing options have boomed in many cities (Loidl et al. 2019).

3.2 Multimodal transport system (MTS)

MTS is commonly defined as using one or more transport modes to complete a trip (Aparicio et al. 2022a) cross mobility is another alternative word used for multimodality. The usage of MTS has enabled the transport system to be effective and coordination between different transport modes has proven to reduce congestion and provide alternative transport modes in case of a malfunction of the existing transport mode (Aparicio et al. 2022b).

With the initiation of sustainable development goals of the United Nations, the need to increase sustainable metropolitan approachability and cater the travelers with high-quality, long-term mobility within the cities has arisen. This can be achieved when sustainable mobility solutions are interconnected and diversified which allows the entire transport system to be effective and robust (Aparicio et al. 2022c).

Many Multimodal transport providers use marketing as a crucial tool when developing MTS. The transport providers promote MTS through service innovation including offering discounts via contracts or making the pricing model attractive by reducing the cost and increasing efficiency to be competitive in the market (Liu et al. 2022). MTS involves one or more individual service providers hence coordination amongst multiple carriers is required however there are many challenges faced by the service providers. One main challenge is to estimate the impact of the interruption of transport modes. The other challenges are organizing the time of transfer to reduce the number of transfers in the direct route and maximize the efficiency of the MTS (Dong et al. 2022). MTS can be offered via a mobile app, and not by transport mode itself as it will be more user-friendly for the traveler to plan the trip as the traveler could choose the desired option from the wide range of mobility options (Yifei et al. 2022).

3.3 Mobilty as a Service (MaaS)

MaaS concept was introduced by Hietnaen as an Ecosystem where customer demand and the suppliers' bundled mobility solutions are integrated via a digital interface of a service provider. Hietanen (2014), defined MaaS as “a single interface that combines different transport modes to offer a tailored mobility package, similar to a monthly mobile phone contract, which could include other complementary services, such as trip planning, reservation, and payment.”

MaaS is not defined as a simple technology feature but instead a new feature as to how transport modes are provided and used (Audouin and Finger 2018).

MaaS evolves around the user and intelligent mobility management with the support of ICT and the service providers who offer various transport options for end users' demands via a single digital platform which allows the users to plan, book, and make the payment (Eltis. org, 2022a).

MaaS is where the mobility services are obtained via a package based on the users' demand and not purchasing the mode of mobility. Maas is a crucial element in discussions with future mobility. Due to intricacies in this field of research, MaaS can be addressed as an emerging field of future mobility that involves a broader vision in mobility, a new information and communication technology (ICT), Changes to traditional user behavior, or a change to overall transport option (Jittrapirom et al., 2017).

3.4 User preferences

The extant knowledge of MaaS users is carried out based on quantitative studies of people with no knowledge or in-depth insight into MaaS (Matyas and Kamargianni 2021). Many studies have been carried out to understand who would opt for MaaS. A study was carried out in MaaS operation countries Finland, England, and Australia and it was concluded that 40% of the adults are willing to opt for MaaS if their entire transport needs are met and the overall cost would be lowered ((Kamargianni et al. 2018; Liljamo et al. 2020; Vij et al. 2020).

A study conducted in Sydney concluded that 50% of the respondents would be subscribed to a MaaS plan. Also, infrequent users of cars have a high tendency to adopt MaaS. However, participants who use or do not use cars daily would not opt for MaaS (Ho et al. 2018).

Socio-demographic characteristics a key to the implementation of MaaS. A study conducted by Matyas and Kamargianni (2021) revealed that the age of the user is a key aspect of shifting to MaaS. A study in the Netherlands discovered the age group of 18 to 34 years tends to use MaaS platforms (Alonso-González et al. 2020) Another study carried out (Sochor 2021) affirmed that Socio-demographic factors commonly discovered as positive influences towards MaaS in density-populated areas. Early adopters of MaaS are extremely mobile, with increased socio-economic levels, higher levels of education, and personal income (Zijlstra et al. 2020).

3.5 Preferences of transport service providers

Service providers of MaaS are a crucial aspect to be analyzed. Public transport providers were identified as "the backbone of MaaS" and if the public sector takes over in operating MaaS it will be easier to work together with everyone being the mobility regulator and authority of the city. Kamargianni & Matyas (2017). Nevertheless, the public sector being a nonprofit organization and a bureaucratic structure, expanding to MaaS service provider, will take a consideration the time and limitations in terms of introducing innovative solutions. On the contrary, if the private sector is the authority to implement and manage `MaaS` overall operation will be quicker, and as the private sector has the capital to invest in innovative solutions. The public sector may not collaborate with the private sector as they think it will tarnish the brand image Kamargianni & Matyas (2017). A crucial element of the MaaS platform is to integrate the entire transport service providers not merely implement the existing transport modes into one platform. This should include "vehicle fleet optimization and relocation strategies" while designing the platform. When it comes to car, bike, and scooter sharing it is vital for the user to know where it needs to be dropped off at the end of the journey. A designated area, where the next user or maintenance team has easy access. The research carried out by Li and Voege (2017), revealed that incorporating public transport providers' real-time data is the key when serving customers via MaaS. This article concluded that some private and public transport providers are reluctant to share real-time information with MaaS service providers which is a limitation when implementing the MaaS platform. In the research conducted by Jittrapirom et al. (2018) on the public sector's view on framing policies for future MaaS implementation, the extended analysis conducted with the experts of public authority discovered that there are various barriers including the culture of the existing public administration, lack of proficiency of Maas Service providers, lack of regularity and insufficient mobility modes to be included in the platform, lack of collaboration with stakeholders, fear of losing control and monopoly of the public sector has been limitations when framing policies for MaaS.

4 RESEARCH DESIGN

The objective of this research is to examine the current demand for MaaS in Germany, the desired mobility modes and additional features and obstacles experienced by the users when opting for mobility solutions via a MaaS platform, and the desired pricing model the users are willing to pay for mobility services.

4.1 Research gap and research questions

Mobility as a service has become an important aspect due to the vast demand for mobility options in smart cities and cities focused on sustainability. Many studies have been researched on smart mobility options, and the important element is mobility as a service. Many authors concluded that user acceptance is the key feature of MaaS. However, there is a research gap in the criteria evaluated by the users before accepting MaaS hence the below research questions were developed for this study.

(1) What is the current customer demand for MaaS?

(2) Which modes of mobility, operational attributes, and obstacles you encountered while using the MaaS platform in Germany?

(3) Which pricing models will be most suitable when creating a MaaS platform in Germany?

5 RESEARCH METHOD

The ultimate objective of this research is to identify the influencing user preferences in implementing the MaaS platform. This chapter further explains the research gap and research questions as discussed in Chapter 1 and the research framework in depth including the selection of the research approach, sample selection, collection, and evaluation of data.

5.1 Research Design

Qualitative approach is chosen from the three commonly used research approaches. Qulitative,Quantitative and Mixed approaches. Since this research focus on user preferences towards MaaS platform, qualitative approach is selected as by nature, qualitative research is social. It takes insights from humans on behavioral models which are exclusive for the selected sample. Data gathered during the interviews are as per the interviewees' experience and observation which makes the information superior.

5.2 Research sampling

A simple random sampling method has been used for this study as the selected sample population. The population has an equal probability to be chosen as the sample population which is an unbiased representation of the population. As De. Jonckheere and Vaughn (2019) stated that respondents who have made themselves available for an interview with the knowledge and experience on the topic to be interviewed would be an ideal selection as the research sample. The sample size is 10 and includes 10 full-time employees within the age group of 30-42 years as per the literature review users with the latest technology usage have the highest potential in accepting MaaS were revealed hence the sample was focused on this age group. The sample was with a mix of both male and female as aforementioned with the insight

of the literature review to understand whether there is an influence in accepting MaaS and pricing mechanism based on the categorization of the gender. The interviews were carried out using Zoom, WhatsApp, and in person. The answers were saved on a password-protected Word document. The interview lasted approximately 30 to 40 minutes. Privacy of the respondents was maintained by the acronym the 10 "respondents" (R) by R1 to R10. The following table provides a summary of the respondents based on their occupation, the mode used for the interview, and the duration of the interview.

5.3 Research method of data collection

Structured interviews were used to gather data. The questionnaire consists of 7 general questions and 6 to cover the 3 research questions. The questionnaire was open-ended as the quality of data will be superior with the insight of the interviewee's experience and observation of the subject. However, the findings will be purely based on the individual's experience, truthfulness, and integrity of the participants which is a disadvantage of conducting a qualitative study. The interview was approximately 30 to 40 minutes.

6 DATA ANALYSIS

Answer scripts were analyzed using content analysis and segregated the findings to the three main research questions. The inductive reasonings were subcategorized. Deductive reasoning was analyzed and compared with the prevailing literature to understand the similarity or deviation. Inductive reasoning was analyzed to understand the requirement of a further research requirement, or any fields not covered by prevailing literature. A summary of the findings was constructed to arrive at the conclusion and recommendations.

7 RESULTS & FINDINGS

The results and findings which were gathered during the interviews are categorized under deductive and inductive which will be further discussed by comparing the point of view of the respondents.

7.1 Current demand toward the MaaS platform

The first research question focuses on understanding the current demand for the MaaS platform. The research is solely focused on the demand for the MaaS platform within Germany.

(1) There is a significant demand for the MaaS platform within Germany as 90% of the the sample is currently using mobile apps for commuting. The main reasons discovered during the interviews for opting for MaaS are, that this option is more cost-effective than owning and maintaining a personal vehicle, easy to use with no stress and focus needed while driving and the current transport system has good connectivity and saves time as there is an option to choose the best possible connectivity based on the time and mode is chosen to reach the destination. These are the main reasons the respondents stated the reason for choosing MaaS.

(2) The most used and desired mode of transportation to be incorporated into the platform is public transport options due to the vast coverage and the public sector operates as a nonprofit generating organization that provides low-cost transport options which is aligned with the literature by Kamargianni & Matyas (2017). All public transport options such as Tram, Bus, S-Bahn, and U-Bahn are the modes included in the platform and from the private sector, as the respondents use E-bikes scooters, and car-sharing options for these modes should be included in the platform. Also, a participant stated to include taxis on the platform as well which is the ideal solution for the time being for first and last-mile connectivity until the mass service providers arrive at a solution.

(3) One of the main factors in increasing the customer base for the MaaS platform by attracting private vehicle owners to shift to MaaS is the punctuality of the transport service providers hence transport providers need to improve on punctuality to attract more customers and increase revenue.

7.1.1 Effectiveness of the MaaS apps

One of the sub-questions under the first research question is to evaluate the effectiveness of the MaaS apps the respondents currently use. Most of the respondents stated that the apps they currently use are effective and have not come across any technical issues or system crashes the interface is easy to use, they are comparatively accurate information on train arrivals and delays, and route planning is efficient in terms of timings and mode of transport to be chosen. However, a few respondents stated that they have experienced issues in connectivity and getting real-time information such as when a ticket is purchased an email confirmation is received but the ticket does not appear on the app in real time, and the app needs to be refreshed for the ticket to appear. The respondent has also experienced the same issue with real-time information on train arrival and departure information. When a new initiative is introduced on transport such as the monthly travel pass to travel across Germany on selected transport options, the previously existing unused online tickets are shown on the app but the feature to use these tickets is disabled as a new product is purchased by the user. The user suggests refunding money for unused tickets or having the option to transfer the tickets to another user. Few respondents stated that some of the apps they frequently use are not user-friendly. When the user has subscribed to a monthly pass, the user would need to manually update the order number on the app and refresh the field monthly for the ticket to be active for the given month.

7.1.2 Usage of public and shared transport modes

The next sub-question of the first research question is to identify the current demand for public

and shared transport options. All respondents stated that they currently prefer to use public and shared transport options. A summary of the answers revealed that the coverage and connectivity of the German public transport sector are vast and cost-effective than owning and maintaining a private vehicle including parking charges and the monthly transport pass available across Germany has attracted more users to opt for public transport option and some corporations reimburse the ticket cost of the employees who use this option. However, if an employee owns a private car the fuel cost is not reimbursed. It could be an initiation drive towards sustainability. Ease of use is another highlight of opting for public transport options. The user can engage in another important task while travelling without any stress as driving a private vehicle. Shared transport options like e-scooters or e-bikes are used for short-distance travel where the travel time is less than the waiting time of the public transport modes. Even though all the respondents stated that they are using public and shared transport modes some respondents stated points to dislike commuting in public and shared transport modes. The main reason is the transport service providers not been punctual. If a transport need is time-bounded those users will opt to use a personal vehicle or shared vehicles to commute. The cost-effectiveness is subjective when a family of four average person's traveling to a destination via public transport option can be more expensive than using a personal vehicle. If the length of the travel is long public transport modes may not be the best option as using a private vehicle provides more flexibility and comfort for the travel. The respondents who use shared transport modes stated that the radius of coverage for e-scooters and e-bikes is less hence they have experienced issues in finding a place to park at the end of the destination.

7.1.3 Interest in MaaS Platform

Except for one respondent all respondents are interested in a MaaS platform. The one respondent who does not like it is not interested as the respondents' travel requirement to use public and shared transport is less and opt for walking as a mode of transport. The main reasons for the interest in the MaaS platform are that it does not need to use multiple apps for planning and booking it can be done via a single platform. All service providers who are integrated into the platform are managed by a centralized customer service hence it is easier to contact for any assistance than getting in touch with the individual service provider's customer service which is a tedious task if a trip is planned via two or more service providers the user has to contact all service providers for any assistance needed to modify or manage the booking, multiple users can be added and arrive at the best possible option which can be planned as a team within the range of their travel budget, the new platform will be able to solve the vacuum experienced in the prevailing apps. R9 stated that it will be useful for both short-distance and long-distance transport where one can view and opt for the most convenient transport option to complete the trip. The usage of public and shared transport options reduces traffic and reduces per-head carbon emissions on the road. However, there is a massive requirement to address the first and last mile of the trip as it is one of the main indicators for users to opt whether to complete the trip via public or shared transport modes or opt for a private vehicle.

7.1.4 Barriers to using the MaaS platform

The main barrier as per their point of view is the reliability of the platform. This is purely depending on the punctuality of the service providers integrated into the platform. For instance, if a multimodal transport mode is opted for a trip, if the user encounters a delay in the first leg it has sequent impacts for the rest of the transport modes selected. If a transport need is timebound, the user will have to take a risk in opting for a public or shared transport option. ICT infrastructure plays a critical role in platforms such as MaaS as the speed of connection and real-time information are the keys for a user to plan a trip. Arrival and departure times, route plan, transit, etc. support planning and booking a trip. Thus, the improvement of ICT infrastructure is a crucial aspect to consider when developing a MaaS platform. In summary, if a platform is created with high-level ICT infrastructure, the objective of the MaaS platform i.e. attracting private vehicle users to opt for public and shared transport options will be feasible. Some respondents stated that the current mobility apps are not user-friendly. Some apps are created in a way the user manually refreshes the ticket to be active, the order number of the ticket should be manually added to the user profile when a subscription pass is selected. One respondent stated that when a transport option is chosen with two transport providers seat selection is not available for the transport provider who is not within the group of the main transport provider. The essence of the findings on the ease of use, and user-friendliness of the platform is beyond

doubt all respondents with or without technical literacy if seeking for. All respondents are highly educated and most of the respondents are attached to the information technology sector with both academic and professional experience, yet they require less human intervention when using a mobile app. Payment option is another possible barrier highlighted by the respondents with the experience. Credit cards should not be the only payment mode.

Some users do not opt to use credit cards due to personal preferences and some would like to use but do not have the predefined criteria to obtain a credit card from an institution. The app should focus younger generation. The findings of the interviews revealed that credit cards issued by service providers outside Europe are at times not supported by the apps hence if a potential user experiences a similar issue there should be other modes of payments integrated into the platform. PayPal, Debit cards, Direct bank transfers, Vouchers, etc. The availability of non-optimal transport options is another barrier when promoting the MaaS platform. If the app provides services with limited-service providers, the best option for a trip will not be available hence the users will directly book from the service provider's site or mobile app. The first and

last-mile connectivity is a crucial aspect when a user decides on a transport mode (Chaturvedi and Srivastava 2022) hence it is critical to embed first and last-mile transport options to connect to and from the chosen transport mode. Two respondents stated that the availability of transport options in rural areas is limited and even the available modes operate infrequently. If a user is planning a trip to a rural destination with limited public or shared transport options, the user will likely opt for a private mode of transportation.

7.1.5 Priorities when selecting a transport mode

The criteria mentioned in the interview questionnaire are cost, convenience, time, safety, and environment. The majority stated cost to be the first criterion when opting for a transport mode. A respondent stated "It is costly to maintain a personal car in Berlin. The proportion of the lease, insurance, and parking costs is quite significant when compared with the take-home salary. Even though it is convenient to use a personal car due to the increased expenses I have decided to use public transport instead". The second priority of most of the respondents is convenience and time. Respondent 3 and Respondent 4 stated as both reside in the heart of Munich the connectivity for all public and shared transport modes are just a few minutes away. The requirement of the transport modes is very more even if the user misses one connection the next connection in the most frequently used transport modes within the city will arrive in five minutes during the daytime and a maximum of ten minutes during the nighttime. R4 stated that

public transport is a better option in terms of convenience than driving your car as driving can be stressful. R2 said "I prefer to work during my commute as the transport modes are comfortable and free and fast WIFI connections are available. Also, I choose a silent zone when I plan to work during my commute. It is a good initiative as the users have the option to select these zones when booking the ticket". If a travel need is time bounded Time is a crucial element when choosing the transport mode. For example. R1 stated as public transport is known to be delayed, the user is not willing to take a risk for a journey that is crucial to be at the destination on a pre-agreed time hence will use the private car to avoid any inconveniences. The users focus

on the cost and time for short-distance and time-bound travel and the cost and convenience of long-distance leisure travel. However, for business travel the users opt for cost, convenience, and time as the prioritizing factors when selecting a transport mode. Both R9 and R10 stated that they consider the environmental factor of carbon emissions when choosing a transport mode. R10 stated "I have no plans to buy my car and I will continue to use public and shared transport options. Also, I am willing to, and I have chosen to travel ten hours via the train rather than opting for a flight of two hours for a recent destination I traveled to. This is mainly due to the lesser or almost zero carbon emission." The research done by Statista revealed that 48% of

the carbon emissions worldwide are attributed to cars and vans (Statista,2023). Safety was the least priority the respondents selected as they consider safety is not an influencing factor when choosing a transport mode from driving their car or opting for public or shared transport mode.

7.2 Preference towards services provided

7.2.1 Preferences towards various mobility options

All the respondents are currently using and continue to use public and shared transport options hence the respondents stated that the platform should include various transport options as it will be beneficial for the

user to select the best possible transport option for the desired destination. However, the three female respondents are not using shared e-scooters. The necessity of including ferry transport was not stated during the interviews but the platform should consider incorporating public transportation via water is also an option across Germany.

7.2.2 Requirement of Additional Features

The important feature stated by all respondents is real-time information on train schedules, delays, and alternative options, etc. Another important feature to be included is an update on any disruptions. Due to the current experience of many trips getting delayed or canceled due to the ongoing strikes, an important feature to be integrated by a couple of respondents was to develop the refund policy in a way that the refund can be requested via the app rather than sending an email for an instance. It will be helpful to keep track of refunds requested and claimed.

7.3 Preferable pricing model and attitude toward using multi-modal transport system

The third research question was developed to understand which pricing model should be integrated into the platform. Whether the users are willing to opt for transport modes via a subscription-based payment plan or when the transport options are used “pay as you go”.

7.3.1 Desired pricing model

Most of the respondents opt for a subscription-based pricing model. The Deutschland ticket introduced in May 2023 has been one of the key factors in influencing the decision of opting subscription-based or pay-as-you-go option. The frequency of travel is another factor in determining the pricing model.

7.3.2 Attitude toward multi-model transport option

All respondents are open to opting for multimodal transport options to commute to an end destination however critical factor in determining whether to choose a multimodal transport option or a single mode of transport option purely based on the purpose of the travel. If the travel is time-bounded with the experiences of delayed transport modes, the respondents are not keen to seek for multimodal transport option as a delay in one connection has an impact on reaching on time for the next connection.

8 ANALYSIS AND DISCUSSION

The main objective of this research is to identify the user preferences for the implementation of

the MaaS platform and close the research gap. The first research question focuses on the existing customer demand for the MaaS platform. The second question pertains to the modes of mobility, operational features, and barriers you encountered while using the MaaS platform and the final question was about the most suitable pricing model to be considered when creating a MaaS platform. This segment provides a summary of the findings which will be discussed by comparing them with the prevailing literature and concluding the findings.

8.1 General information about the participants in this research

The general information of the respondents can be summarized as follows. 70% of the participants are within the age bracket of 36-40 years, 10% each in age brackets of 25-30 years,31-35 years, and 41-45 years. 70% of the participants are males and 30 % of the participants are females. 40% of the participants are single, 30% of the participants are married and the balance 30% are married and have a child under 10 years old. 100% of the participants are full-time employees with a hybrid work model. 80% of the participants are working in the information technology sector, 10% in the field of finance, and 10% in research. 10% own a private car and 50% own a bike however 100% of the participants use public transport options. Such as Bus, S-Bahn, Train, U-Bahn, and Tram, and the frequency is almost daily. 60% of the participants use shared transport options E-scooters, bikes, and cars. However, for 60% of the participants who use shared transport options, the frequency is rare. None of the participants were below 30 years all participants were employed in a full-time position, and all are working on a hybrid work model hence the results of the findings will be skewed towards the preferences of middle-aged, income-generating, and educated participants.

8.2 Investigation of the current demand for the MaaS Platform

8.2.1 Usage of transport mobile applications for mobility

90% of the participants were using mobile apps to plan, book, and purchase tickets for their commutes and only 10% did not use mobile apps to plan their commuting requirements.

8.2.2 Motivation to use MaaS platform

All participants are open to using public and shared transport modes. The main factors for most of the participants are cost, convenience, and time. Some also prioritize these options based on environment-friendly and safety aspects. All the participants informed that creating a MaaS platform is an excellent proposal as they will save money when using a single platform for all travel requirements, do not need to use multiple apps when planning, booking, and making payments towards a trip, and centralized customer service function of the app which will support irrespective of which service provider has been used.

8.3 Investigate service design preferences for MaaS

Modes of mobility, service functions, and obstacles encountered while using the MaaS platform.

8.3.1 Preferences towards multi-model options

MaaS platform should be purely based on the users' requirements hence it is crucial to understand the requirements of the users. Such as the transport options, support services, and additional services the users seek while using the application (Kamargianni & Matyas,2017). All the participants are using public transport options, and they will continue to use public transport due to the benefits they receive. 70% of the participants use shared transport options such as Über, Freenow, Bolt, Tier, and Bla Bla cars. The main reason to choose public transport is due to the efficiency in cost, ease of use and convenience.

8.3.2 Operational attributes to incorporate in the MaaS Platform

Based on the interviews the below findings were observed as primary and secondary features to be implemented in the MaaS Platform.

Primary Features: Real-time Information, Disruption warnings, Parking Information, Chatbot Option and AI-Integration, Trip planning, booking and payment, Alternative route Options. Secondary Features: Price Alerts, Description of the destination, Customization, Travel Point System, Request for refunds via app, Driver/owner rating on car sharing.

8.3.3 Potential barriers to overcome when creating the MaaS platform

As per the interviews, the participants informed that there are barriers they foresee when using a MaaS platform hence these barriers would need to be looked at when implementing the platform.

(1) Reliability

(2) Information and Communication Technology – ICT

(3) Complicated user interface and user experience

(4) Issues faced at the point of payment and ticketing.

(5) Nonoptimal transport options

8.4 Investigate Pricing mechanism for MaaS

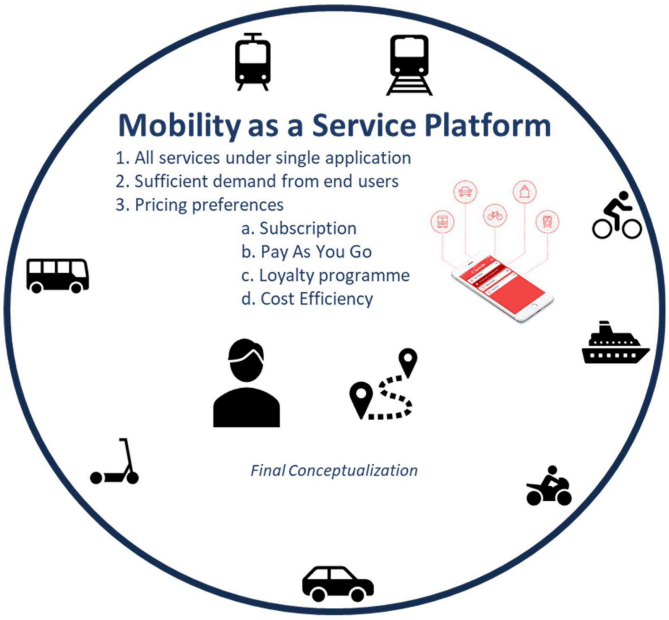
8.4.1 Preferences for Pricing

40% of the participants chose the pay-as-you-go payment option as the frequency they travel is less hence paying for a daily pass or monthly pass is expensive than purchasing tickets when the transport requirement occurs. However, 60% of the participants opt for subscription-based pricing packages as they travel frequently however with a flexible cancellation policy and without any penalties or contractual commitments. Some of the participants mentioned that the decision to opt for the preferred payment mode is seasonal as some prefer to use their bikes to commute in Summer and opt for public or shared transport modes during winter. Also the participants is only willing to pay a subscription for a daily commute and not

willing to pay a premium price for transport coverage outside the vicinity the participant is not commuting to.

8.4.2 Preferences for multi-model transport bundle packages

All the participants stated that they are willing to opt for multi-model transport options as the multi-model option will provide various alternative routes provided by the registered transport providers of the app and this will help to regulate pricing by service providers and reduce the monopoly created by the transport service sector.



9 CONCLUSION

The research is carried out to fulfill the research gap of identifying “user preferences in opting for MaaS in Germany”. The answers to the three research questions were analyzed based on content analysis.

9.1 Current demand for MaaS

This research question was constructed to understand the current demand for the MaaS platform in Germany. After analyzing the responses to this question, the below points can be concluded.

(1) All respondents are using the MaaS platform to fulfill their day-to-day travel requirements. Use of public and shared transport options are cost-effective, flexible, and more convenient modes of transport than using a personal vehicle. A single platform to plan, book, and pay benefits the users by saving time and convenience rather than using multiple apps for transport.

(2) All available public transport modes and shared transport options such as cars, escooters,e-bikes, and taxis of private transport providers should be integrated into the platform. Water transport options such as ferries were not mentioned during the interviews, but this mode is recommended to be included as well.

(3) The punctuality of the service providers has a great influence in opting for public and shared transport modes and converting private transport users to public and shared transport users.

9.2 Modes of mobility, operational attributes, and obstacles in the MaaS platform

(1) All forms of transport options should be included for the users to select the best possible connections.

(2) The below attributes are suggested to integrate to the application.

(3) The below obstacles should be overcome to attract and retain the users.

(a) Reliability – Real-time information should be accurate and inform the users of train delays and strikes well in advance for them to seek a possible alternative, a high level of transparency, and punctuality of the service providers.

(b) ICT – The platform needs to be developed based on advanced ICT infrastructure which will be the turning point for the users who use MaaS platforms created by other providers.

(c) Complicated user interface and user experience – User-friendly, easy, and minimum manual intervention of processes

(d). Issues faced at the point of payment and ticketing – All available credit cards and the facility of making payments via debit card, bank transfers, and PayPal should be an option for users who do not own credit facilities. Furthermore, invest in reliable payment getaways.

(e). Nonoptimal transport options – Usage of AI to understand the best routes in terms of cost and time savings.

Primary Features	Secondary Features
Real time information	Price alerts
Distruption warnings	Description of the destination
Parking information	Customization
Chatbot option and AI integration	Travel point system
Trip planning,booking & payment	Request for refunds via app
Alternative route options	Driver/owner rating on car sharing

9.3 Preferable pricing model and attitude toward the multimodal transport system

9.3.1 Pricing model

The preferred pricing model can be concluded as below.

(1) Subscription-based pricing model with monthly and annual subscriptions to attract

frequent travellers.

(2) Pay-as-you-go-single ticket purchases as and when travel requirement arises for

infrequent travelers.

(3) Consider discounts and bonus points for both subscription and pay-as-you-go options

to attract both types of travelers. i.e. Frequent and infrequent.

(4) “Cost-effective” is a critical factor considered by the users hence developing attractive cost-effective travel packages for all users.

9.3.2 Attitude toward a multimodal transport system

(1) Predesigned packages with several modes of travel will be attractive to users.

(2) Ability to create customized packages with various modes of travel options.

(3) Incorporate as many service providers as possible to provide multiple alternative travel options.

(4) Include service providers who provide taxi services to fulfill the first and last-mile requirements.

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A Comparative Analysis on the Impact of Culture, Norms and Attitudes on the Adoption of Eco-Friendly Transportation in Mannheim and Tokyo

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1 ABSTRACT

In the conversation on eco-friendly practices, the role of cultural values, norms, and attitudes as to sustainable urban transportation remains crucial yet still understudied. A lot of work has been done to identify the facets of sustainable transportation, yet there exists a gap of how culture elements shape the adoption and effectiveness of eco-friendly practices (Brown & Wang, 2018). This exploratory comparative qualitative research in progress investigates the key indicators derived from cultural values, norms, and attitudes on the adoption and effectiveness of eco-friendly transportation practices in Germany (such as Freiburg) and Japan (such as Tokyo).

Keywords: adoption, attitudes, social norms, culture, sustainable transportation

2 INTRODUCTION

Transportation is the spine to the development of urban areas (Chattaraj and Ujjal, 2003). From walking to public transportation and then varieties of automobiles, factors such as economic development, creativity and availability of high technology have been the reasons behind the tremendous advancement in urban transportation. Urban transportation may be referred to as transfer (of people and goods) system that embraces all elements of transportation, including the infrastructure, rolling stock, and traffic flows, in a city as a functioning entity. Its elements include Metro-Subway-System; Bus System; Shuttle System; Transit rail System; Paratransit System; Taxi System; Private vehicles; Cycling; walking; and others. Factors such as culture, cost, comfort, distance, safety, and journey duration determine the choice of paths in the development of urban transportation planning. According to United Nations (2018), urban transportation increased from 2% in 1800 to 50.16% in 2007 and it is expected to reach 68.36% in 2050. In the era of sustainable urban living and eco-friendly practices, it is important to understand the cultural underpinnings of transportation choices which has become increasingly apparent (Doe & Johnson, 2021). Germany and Japan portray diverse cultural values and different approaches to smart cities' development. Analyzing the cultural fabrics of Freiburg and Tokyo, this research strives to fill the gap highlighting the influence of social norms, examining carefully decision-making processes, and evaluating the cultural sensitivity embedded in community engagement narratives (Wong & Kim, 2018; Patel et al., 2019) which influence transportation behaviors and policies. Tokyo is densely populated with urban transportation systems such as Tokyo Metro; JR East (Japan Railways East); Japan Railways (JR) Toei Subway; Buses; Tokyo Monorail; Tokyo Water Bus; Taxis; Cycling; Walking; Car Rentals and Car-sharing Services etc.

3 RESEARCH AIM

To systematically examine and understand the interplay between cultural and social dimensions shaping the adoption of sustainable transportation practices in Germany (Freiburg) and Japan (Tokyo).

4 SYSTEMIC LITERATURE REVIEW: THE IMPACT OF CULTURAL VALUES, SOCIAL NORMS AND INDIVIDUAL ATTITUDES

4.1 Initial Research Gap

Very little has been done on how cultural, norms and human behavior shape the adoption of sustainable transportation (Sedita, 2020). Some discovery of not having enough data on aged drivers, unavailability of bigger sample sizes, and no existence of psychological data on behavior (Mohapatra et. al., 2023).

4.2 Acceptance of Eco-friendly Practices

Culture shapes individual behaviors and societal structures (Smith et al., 2020; Jones & Lee, 2019). Many studies have examined the effect of culture on sustainable development but very little has been done on how human behavior shapes the adoption of sustainable transportation (Sedita, 2020). There is a current lack of knowledge on aged drivers, unavailability of bigger sample sizes, and no psychological data exist on behavior (Mohapatra et. al., 2023). Therefore, this research investigates how cultural dimensions influence sustainable transportation adoption and outcomes in Germany and Japan. Germany and Japan portray diverse cultural values and also show different smart city development methods. Analyzing the cultural fabric of Germany and Japan will display the role of culture in influencing transportation behaviors and policies. To fill the gap, the work researches on the influence of social norms, and examine decision-making processes, as well as the role of cultural sensitivity embedded in community engagement narratives (Wong & Kim, 2018; Patel et al., 2019). The extent to which culture explains transportation choices (Doe & Johnson, 2021) and fosters eco-friendly transportation practices and its success implications will be investigated. By exploring how societal expectations and peer influences mold transportation choices, the study aims to model the role of social conformity and divergence in shaping sustainable mobility patterns in Germany and Japan. Individual attitudes toward transportation, influenced by personal beliefs, experiences, and perceptions, play a pivotal role in shaping sustainable mobility behaviors. This study conceptualizes how individuals in Germany and Japan perceive and respond to eco-friendly transport practices. By examining individual attitudes, the research aims to discern the factors that contribute to or impede the acceptance of sustainable transportation options. The effectiveness of eco-friendly transport practices is measured not only by their environmental impact but also by their integration into the daily routines of urban dwellers. This research conceptualizes effectiveness as a multidimensional construct, encompassing factors such as adoption rates, behavioral changes, and the overall success of sustainable transportation policies in both Germany and Japan. The acceptance of eco-friendly transport practices involves the embrace of sustainable transport as a cultural norm. This research conceptualizes acceptance as a holistic concept, considering factors such as public perception, willingness to adopt, and the integration of eco-friendly transport practices into the broader societal fabric.

At this stage, the research methodology comprises a systematic and an additional narrative literature review. Regarding the systematic literature review, an online database search was conducted with the following key words: sustainable practices; social dimensions; culture; and urban transportation. Initially, seventeen thousand and six hundred (17,600) articles were identified. Two-hundred and twelve (212) titles were selected but ninety-seven (97) articles were selected for relevance. Twenty-e (19) articles were selected for full text review, out of which nineteen (13) passed the inclusion and exclusion criteria Finally, only eleven (11) articles passed the quality assessment process adapted, thus, validity, credibility, reliability, and integrity. An additional narrative literature review, to assure the consideration of most updated research, was conducted on specific relevant research in German and Japanese cities. The extraction process resulted in initial conceptualizations which will be presented at the conference. In addition, based on the initial conceptualizations, a research design for a consecutive, comparative empirical study is suggested favoring a mixed method triangulation approach.

4.3 Selection Criteria

Time frame: The time framework for this study was set from the genesis of sustainability by the United Nations in 1984 until 2023, to identify enough indicators that drive sustainable urban transportation.

Language: English, due to the language limitations of the researcher.

Study topic: The researcher terminated studies with zero value to the research questions for final selection and included necessary research papers to achieve the aim of this study.

Study type: For high quality information, this study eliminated all relevant literature external to the primary classification.

Methodology: Qualitative methodology.

4.4 Quality Assessment

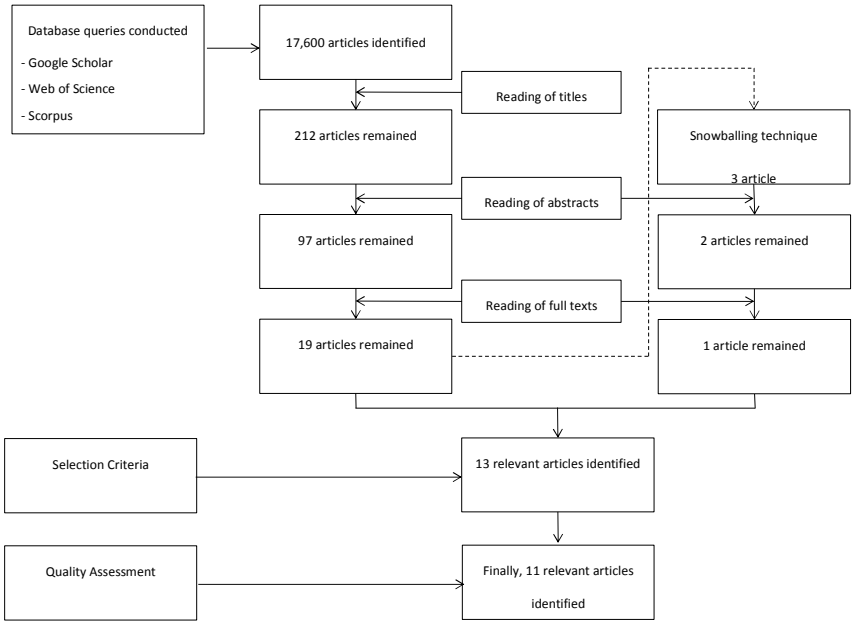
Validity – focused on the accuracy and potency of the study measurement in respect of the research questions for this study.

Reliability – the replicability and the degree of usability of the result now and the future.

Credibility – the requisite academic qualification to be able to carry out the research. Moreso the impact factor of the journal into which the studies were published.

Integrity – research that constitute trust and confidence in the methods applied and the findings.

4.5 Flow Chart



4.6 Data Extract Form

No# of study	Title	Author/s	Publication	Year of publication	Methodology	Population	Results
1.	The effect of transport infrastructure (road, rail, and air) investments on economic growth and environmental pollution and testing the validity of EKC in China, India, Japan, and Russia	Yuanhao Liu Arshad Ali Yuanchun Chen Xiao She	Environmental Science and Pollution Research (2023) 30:32585–32599 https://doi.org/10.1007/s11356-022-24448-w	December 2022	Qualitative Method	Japan China Russia India	The development of infrastructure through revolutionary technologically pro- ficient and advanced transportation systems can improve environmental quality by reducing energy consumption in transportation and resource use (De Souza et al. 2018; Koh et al. 2020). Asian countries should subsidize private R&D activities to increase the affordability of supply of clean energy and renewable investment projects.
2.	Urbanism as it should be: An overview of Environmental Urban Movements and Initiatives towards Sustainability.	Waala A. Yakoub, Mahmoud F. Mahmoud, Osama M. Abo El-Enein, Ghada M. Elrayies	Second International Conference (Tenth Conference of Sustainable Environmental Development), Sharm El Sheikh, Egypt (pp. 16-20).	March 2019	Qualitative Method	Eleven (11) types of eco-friendly urbanism	This study resulted in concept of "a conservation- oriented and environment-friendly society", which can be achieved by applying a new policy emphasized on "harmony between humanity and nature" has emerged.
3.	Sustainable Urban Transportation Criteria and Measurement — A Systematic Literature Review. Sustainability	Kraus Lisa, Heike Proff	Journal for Sustainability, Volume 13, Issue 13: 7113.https://doi.org/10.3390/su13137113	June 2021	Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)	21 papers from journals listed in the German rating system JOURQUAL3 (JQ3) and published between 2010 and 2020.	The research confirmed with the supposition that the environment is of existential importance to social and economic dimensions
4.	Incorporating energy efficiency in urban planning: a review of policies and best practices	Aniekan Akpan Umoh, Peter Efosa Ohenhen, Onyinyechukwu Chidolue, Bright Ngozichukwu, Adetomilola Victoria Fafure, and Kenneth	Engineering Science & Technology Journal P-ISSN: 2708-8944, E-ISSN: 2708-8952, Volume 5, Issue 1, P.No. 83-98, January 2024 DOI: 10.51594/estj/v5i1.729	January 2024	Qualitative Method	Tokyo Vancouver Copenhagen Singapore	Future urban planning initiatives should prioritize the seamless integration of energy-efficient policies into broader urban development strategies. Rather than treating energy efficiency as a standalone aspect, it should be woven into the fabric of comprehensive policies that address

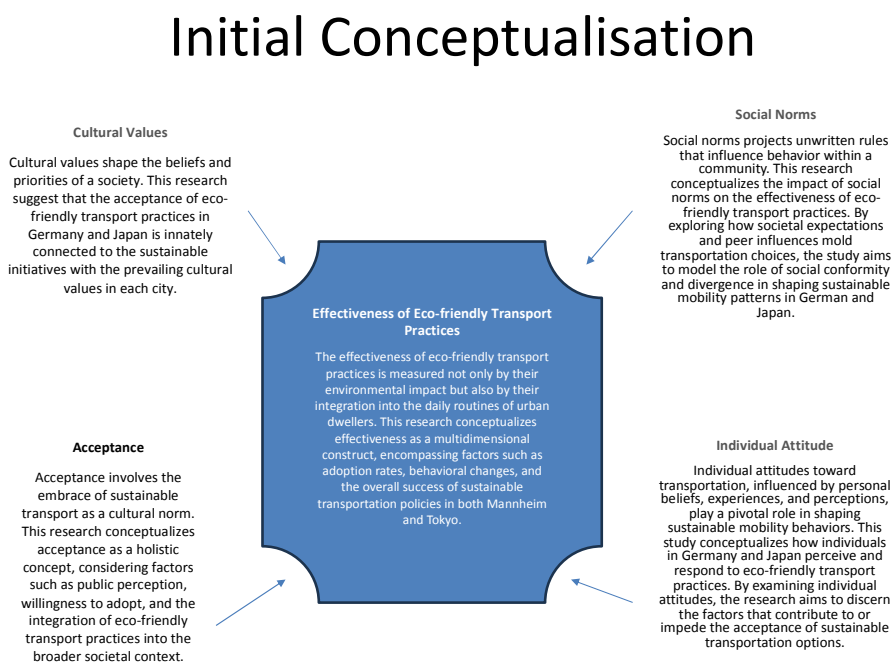
5.	Pedestrian Behavior in Japan and Germany: A Review	Lorena Hell, Janis Sprenger, Matthias Klusch, Yoshiyuki Kobayashi, and Christian Müller	German Research Center for Artificial Intelligence (DFKI)	July, 2001	Quantitative Method	Japan and Germany	For the application of autonomous driving, this is of utmost importance. It is not sufficient to consider the differences in regulations and infrastructure, but in the culturally influenced behavior in general. Research on pedestrian behavior should be always considered in the cultural context of the study and more research of the cultural differences of pedestrian be- havior is required to enable autonomous vehicles to interact safely and reasonably with pedestrians in different countries.
6.	The cultural barriers to a low-carbon future: A review of six mobility and energy transitions across 28 countries	Benjamin K. Sovacool, and Steve Griffiths	Renewable and Sustainable Energy Reviews 119 (2020) 109569	March, 2020	Qualitative Method	28 countries	Culture demands new forms of research and the input of local communities into the research and planning process as well. In the government, policymaking, and planning domains, ministries and statistical agencies responsible for energy, climate, and buildings should begin to collect data on culture and cultural trends. Governments to stipulate greater community involvement during licensing and permitting discussions so that cultural bias is minimized. Group-based and collective phenomena—such as culture—shape and influence aspirations, capabilities, and agency for low-carbon transitions
7.	An Eco-Friendly Multimodal Route Guidance System for Urban Areas Using Multi-Agent Technology	Abdallah Namoun, Ali Tufail, Nikolay Mehandjiev, Ahmed Alrehaili, Javad Akhlaghinia, Evtim Peytchev	Appl. Sci. 2021, 11, 2057. https://doi.org/ 10.3390/app11052057	February, 2021	Quantitative Method	Nottingham (UK), Sofia (Bulgaria)	Our validation results demonstrate the effectiveness of personalized multimodal route guidance in inducing a positive travel behavior change and the ability of the agent-based route planning system to scale to satisfy the requirements of traffic infrastructure in diverse

No# of study	Title	Author/s	Publication	Year of publication	Methodology	Population	Results
8.	The Current Status of Hydrogen Energy Industry and Application of Hydrogen Fuel Cell Vehicles	Mile Zhao	Highlights in Science, Engineering and Technology, Volume 59, 97-102.	July, 2023	Qualitative Method	China, and Japan	Hydrogen energy is becoming more popular as a clean supplemental energy source as the shift to a low-carbon energy framework is accelerated globally. Hydrogen vehicles are more environmentally friendly and convenient to get energy than conventional fossil fuel powered automobiles.
9.	Eco-Cities — A Global Survey 2011	Simon Joss, Daniel Tomozeiu, Robert Cowley	University of Westminster International Eco-Cities Initiative	September, 2011	Qualitative Method	178 countries from the globe	Freiburg (Germany) and St. Davids (United Kingdom) are vying to be the 'greenest city' of Europe, …with international projects such as Tianjin Binhai Eco-city and the four eco-cities planned in the Delhi-Mumbai Industrial Corridor with input from Japan
10.	Introduction to Sustainable Transportation. Policy, Planning and Implementation (2nd edition)	Preston L. Schiller, Jeffrey Kenworthy	Journal of International Planning Studies	November, 2017	Qualitative Method	USA	The book concludes with a discussion of the most vital actions, preparations and measures that need to be taken at several levels to move from conventional to sustainability ransportation. For example, the need for leaders who lead; citizens who participate in effective and well informed ways, often 'leading their leaders'; NGOs and transportation pro fes – sionals, including academics, as well as government institutions that are transformed and move in a more sustainable direction for the 'long haul'.
11.	How is a Sustainable Society Established? : A Case Study of Cities in Japan and Germany	Tsuyoshi Sato	EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 03, Issue 02, pp. 25-35	September, 2016	Qualitative Methos	Kitakyushu (Japan) and Emscher (Germany)	The comparative investigations into their revitalization periods uncovered three commonalities: the presence of a symbol of an environmentally friendly society; a regional organization that manages projects with a comprehensive view; and the use of regional tangible and intangible resources created in the

12.	Conditions of success in sustainable urban transport policy change in 'relatively successful' European cities	Stefan Bratzel	Transport Reviews https://doi.org/10.1080/01441649929560 0	November 2010	Qualitative Method	Zurich, Basle (Switzerland), Amsterdam, Groningen (The Netherlands) and Freiburg (Germany).	Social crises and impressive political mandates were identified as important external factors that influenced the 'greening' of urban transport in the relatively successful cities. However, an open macro-window is only conceived as a political opportunity for change, a necessary but not sufficient condition.
13.	Cultural dynamics and sustainable consumption: a perception of brazilian students in germany	Iveltyma Roosemalen Passos Ibiapina, Sérgio Henrique de Oliveira Lima, Áurio Lúcio Leocádio, and Diego Sampaio Vasconcelos Ramalho Lima	RGSA – Revista de Gestão Social e Ambiental: DOI: https://doi.org/10.24857/rgsa.v15i1.2714	September 2021	Qualitative Method	participant and non-participant observations and ten business students (six women) aged between 22 and 26	Participants perceive the influence of cultural differences on their consumption behavior. In addition, both material culture (e.g., objects, institutions, and organizations) and language and communication systems (e.g., verbal and non-verbal communication) influence their sustainable consumption practices. Ultimately, this configures a dynamic process of adaptation to the new cultural context in which they live.

5 INITIAL CONCEPTUALIZATION

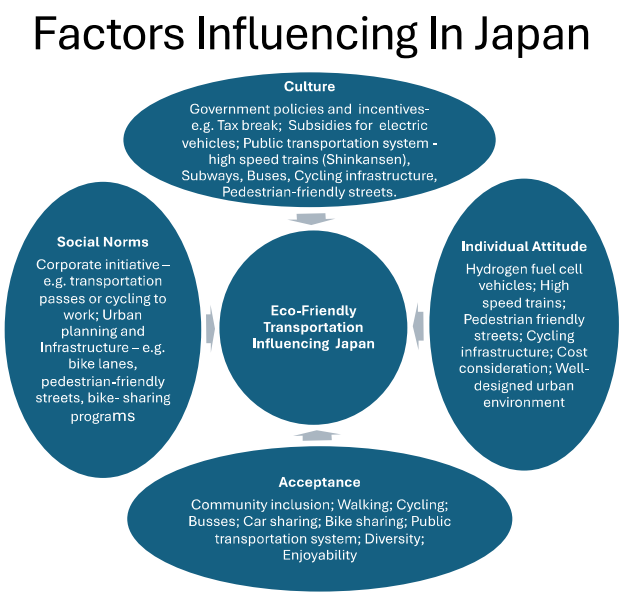
5.1 Overall Factors



5.2 Initial conceptualizations: factors influencing in Japan and Factors influencing in Germany

5.2.1 Factors in Germany

5.2.2 Factors in Japan



5.3 Summary of how the German and Japan Factors Differ

In summary, Germany and Japan prioritize eco-friendly transportation, their methodologies differ slightly due to differences in infrastructure, cultural norms, and government policies. Germany places emphasis on environmental awareness and policy incentives. Japan focuses on efficiency, technological innovation, and adaptability to its unique urban landscape and societal values.

6 RESEARCH DESIGN TABLE

Interlinking Research Objectives, Research Questions, Interview Questions, and Informing Sources – For the Quantitative Part

Research Objectives	Research Question	1. Research Interview	Sources
Conduct a comprehensive analysis to explore the cultural values prevalent in Japan and German and their impact on residents' perceptions of sustainable transportation options.	What are the key sustainable transportation policies implemented in Germany? What are the key sustainable transportation policies implemented in Japan?	1. Kindly describe the key sustainable transportation policies that have been implemented in Germany and elaborate on how these policies were introduced and integrated into the existing transportation framework? 2. Kindly describe the key sustainable transportation policies that have been implemented in Japan and elaborate on how these policies were introduced and integrated into the existing transportation framework? 3. What impacts or changes have been observed since the implementation of these policies? 4. How were the various local communities involved in the development and execution of sustainable transportation policies? 5. What difficulties or success factors were achieved in support and cooperation from the communities contributed to the effectiveness of the implemented policies?	(Brown and Wang, 2018); (Umoh et al., 2024); (Schiller, P.L., and Kenworthy, J., 2017); (Zhao, M., 2023); (Muchlsin, M., 2012); (Ibiapina et al., 2021); (Sato, T., 2016); (Hell, Sprenger, Klusch, Kobayashi, & Müller, 2021)
Investigate the role of social norms in shaping transportation choices, focusing on how these norms influence the adoption of eco-friendly practices in the urban contexts of Germany and Japan.	How do cultural and social dimensions in Germany influence residents' perceptions and attitudes toward sustainable transportation options? How do cultural and social dimensions in Japan influence residents' perceptions and attitudes toward sustainable transportation options?	6. How do cultural values in German shape residents' preferences and choices in transportation modes, and to what extent do these preferences influence sustainable transportation options? 7. How do cultural values in Japan shape residents' preferences and choices in transportation modes, and to what extent do these preferences influence sustainable transportation options?	(Schiller, P.L., and Kenworthy, J., 2017); (Zhao, M., 2023); (Hell, Sprenger, Klusch, Kobayashi, & Müller, 2021); (Sovacool, B. K., and Griffiths, S., 2020);
Analyze how cultural factors influence the decision-making processes of policymakers and urban planners concerning the development, implementation, and evaluation of sustainable transportation policies in Germany and Japan.	Which cultural and social dimensions shape the citizens' adoption of sustainable transportation practices and how do these norms differ between Germany and Japan?	8. Are there specific cultural factors that either facilitate or hinder the acceptance of eco-friendly modes of transportation?	(Zhao, M., 2023); (Muchlsin, M., 2012); (Ibiapina et al., 2021); (Schiller, P.L., and Kenworthy, J., 2017);
Evaluate the degree of cultural sensitivity incorporated into community engagement initiatives promoting sustainable transportation and assess its impact on the success of these initiatives in both Germany and Japan.	Which cultural and social dimensions hinder the citizen's' adoption of sustainable transportation practices, and how do these norms differ between Germany and Japan?	9. In your opinion, what role do social networks and interactions play in shaping people's decisions regarding the adoption of eco-friendly transportation options? 10. Are there social pressures or expectations that affect whether individuals choose sustainable transportation options, and if so, how do they manifest	(Hell, Sprenger, Klusch, Kobayashi, & Müller, 2021); (Sovacool, B. K., and Griffiths, S., 2020); Goldman, T., and Gorham, R. (2006)

7 METHODOLOGY

- Case Study Methodology: The study focuses on in-depth exploration of transportation policies of Freiburg and Tokyo and examines the real-life cultural situations in detail, to understand the complex phenomena within their natural context.
- Research objectives: Conduct a comprehensive analysis to explore the cultural values prevalent in Japan and German and their impact on residents' perceptions of sustainable transportation options; Investigate the role of social norms in shaping transportation choices, focusing on how these norms influence the adoption of eco-friendly practices in the urban contexts of Germany and Japan; Analyze how cultural factors influence the decision-making processes of policymakers and urban planners concerning the development, implementation, and evaluation of sustainable transportation policies in Germany and Japan; Evaluate the degree of cultural sensitivity incorporated into community engagement initiatives promoting sustainable transportation and assess its impact on the success of these initiatives in both Germany and Japan; to gather information about norms, opinions, attitudes, and behaviors and their effects on residents' perceptions of eco-friendly transport options. Additionally, the study will examine some key indicators of social norms influencing transportation choices and address how cultural elements shape decision-making among policymakers in creating sustainable transportation policies. toward eco-friendly transportation.
- Research Strategies: Case study; Survey; and Document analyses.- start with qualitative and then validate with quantitative research.
- Data collection method: Interviews; Fully structured questionnaire
- Time horizons: Cross sectional study
- Population: urban dwellers: Germany/Freiburg (236,140); Japan/Tokyo (37,194,000)
- Sampling Techniques: Convenient sampling (i.e. selection of Freiburg and Tokyo); Convenience sampling and significance testing (i.e. selection of cases)
- Sample size (based on online communities)
- Case Study: Twelve (12) to Fifteen (15) urban dwellers respectively in Freiburg and Tokyo;
- Survey: 500 online questionnaires
- Data analyses:
    - Qualitative: The study will use MAXQDA, a comprehensive qualitative data analysis software that supports various qualitative research techniques.

- Quantitative: descriptive and explanatory; multivariate analysis (multiple regression analysis; SEM (Structured Equation Modelling), Cluster Analysis

- Ethical Consideration: The researcher will adopt ethical behavior such as voluntary participation in the research, keeping anonymity, destroying recorded data immediately after the analysis.

8 CONCLUSIONS

The adaption of eco-friendly transportation technology requires considering cultural factors beyond regulatory and infrastructural differences. Pedestrian behavior, for example, differs significantly across cultures, resulting in context-specific research to inform the design and deployment of eco-friendly transportation choices. Incorporating community viewpoints, in research policymaking and planning is crucial to foster development and tackle urgent societal issues. When it comes to eco-friendly transportation comprehending cultural subtleties becomes especially vital in ensuring the safety, acceptance and efficacy of emerging technologies. By encouraging participation from communities and prioritizing policies that promote conservation efforts societies can strive for a balanced connection, between humans and nature safeguarding the well-being of current and future generations. This approach will strengthen the legitimacy of policy interventions and also promote social cohesion and trust between stakeholders. The result of this research will contribute not only to the academic fraternity of smart city developments but also to the development of practical, indicative cultural strategies that can be applied in Freiburg, Tokyo, and serve as a References

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About the "Soundscape": Are you a Pro or a Con?

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1 ABSTRACT

There are two meanings of the term "soundscape". One is pragmatic, and means the noise in a public place, that one wants to reduce, in general. The other is wider and theoretical. The approach of the paper follows the career of this notion of soundscape, the theoretical one. The notion is useful, in particular in the field of culture. But it is an urban legend. In urban planning, the soundscape cannot have an important role. The residents want quiet public places. It remains that there is a stake of urban governance: it concerns these places where feasts occur, generating too much noise from the point of view of the residents.

Keywords: planning, city governance, soundscape, public places, noise

2 INTRODUCTION

In general, a soundscape is the sonic footprint, or signature, of some phenomenon. It exists in many fields. In science and Art, it is a serious notion. In social matters, it is an urban legend. But it has some presence and utility. The paper will try to explain that.

An example of soundscape in science is noise under water. Under the water, to detect a phenomenon, one uses sounds (hydrophones, sonars…) and on land or in the sky, one uses visual signs or waves (radars …). For instance, each submarine has its own sonic signature, which can be recorded, analyzed by computers … and even recognized. In the countries with a modern navy, there are repositories of these submarines' signatures.[1] This is shown in the French movie "Le chant du loup" ("The wolf's call") which seems to be well documented on this topic.

In Art, let us take the example of the famous French composer Olivier Messiaen. He was also (a little) ornithologist. Often, in the countryside, he listened to birds' songs, noticing the notes on a musical score … It was easy at this time… After, it was the source of inspiration for pieces of piano he composed. A movie can have its own soundscape, but it remains that it is an artefact. The French composer Pierre Schaeffer, who invented the "concrete music" reworked the recorded sound of a locomotive ("Etudes de chemin de fer", "Studies of railroads"). "Pacific 231" is a piece of music for orchestra composed by Arthur Honegger, imitating the noises of a locomotive. Here the soundscape is a serious notion: there is a reality, but it is only the starting point to construct an artefact.

In social matters, the soundscape could be the sonic signature of some community or group. The word has been invented by a Canadian composer, Murray Schafer, in the 70's. His book, "Tuning the world: the soundscape" is deliberately holistic, considering the biological world and the social world, both (Murray Schafer, 2010). Also, the book sets out a program, the "sonic design". The goal is to preserve and promote the "sonic print" of a community. The soundscape in this meaning would be a sound marker of the identity of a community. But scientific research on the topic is unable to clearly identify this sound marker of communities, today (Wolaszin, 2012). An argument (in favor of the existence of soundscape in this sense) is that without hearing noise one dies. This does not hold. To hear no noise is impossible. In a very deep silence, one hears the sounds of one' s own body. Also, there are deaf people. They do not die. But they suffer from solitude. The proponents of the theories of Michel Foucault, when they study the effects of media (that they describe thanks to the metaphor of the Bentham' s panoptic), speak of solitude and confinement. But what makes bearable this solitude and this confinement is the media themselves, not the soundscape. In other words, the emptiness that the media generate in the people' s life is fulfilled by the media themselves. Of course, the soundscape of communities existed in the past, at the time of tribes. But this has disappeared. Ethnomusicologists know that the music they record is disappearing, the records are useful to preserve this music from oblivion. Perhaps the soul of this music survives in the music of Debussy, or Ravel, or Godowsky, or in jazz.

[1] Thirty years ago, the RMA (Revolution in Military Affairs) stated that technology was upsetting all aspects of war. Indeed, it has been checked for soundscapes. Another example is drones.

It remains to explain why one speaks of soundscape. The notion has some presence and is useful.

The approach of this paper consists in explaining the soundscape as a part of a trio: Bentham’ s panoptic, soundscape and chosen sound.

We shall describe the meanings of this trio in the following chapters. In the conclusion, one will try to set out what are the consequences of the soundscape, when the cities are concerned.

3 THE IMPOSED SOUND OR THE BENTHAM’ PANOPTIC

The sonorizing of public places often occurs: stores, malls, fairs, events … The British composer and musicologist Constant Lambert described a sonorized street in Great Britain, in the 30’s (Lambert, 1948). The author has observed a large avenue in Peking, in the fall of 1990, where many loudspeakers were diffusing songs all the daytime. The sound is chosen by some person, a “personality” or a DJ (Disk Jockey). The goal is unclear. Adorno, in “Introduction to the sociology of music” recalls that there is pre-musical: let us quote war music, penitentiary music, work music (Adorno, 2009).[2] The goal of the sonorized public spaces could be … people getting tired. According to the famous zoologist Konrad Lorenz, experiments have shown that tired animals are more easily influenced (Lorenz, 2018). So, human beings tired by noise will be more easily influenced by advertising or by the sight of attractive goods. In his book “Discipline and punish”, the French philosopher Michel Foucault has commented the famous Bentham’ s panoptic (Foucault, 1993). The device invented by Bentham was really followed to build prisons, even if there are no many examples. It was conceived for any kind of surveillance, for instance hospitals, or workshops were considered. The device is a central tower where are the wardens, surrounded by a circular building with the cells where are the people under surveillance (Vaucheya, 1987). There are no walls in the cell, facing the tower. The wardens see all the people living in the cells. The idea is a monopoly of the useful signs, which are produced and circulate. Here, the visual signs show the supervised to the supervisors. The supervisors benefit from a plunging view over the supervised. They miss nothing … For Foucault, the Bentham’ s panoptic is the metaphor of the surveillance society which achieves the obedience of anybody, imposing solitude and confinement.

For the French geographer Jean Pascal Vauchey the sonorizing of public places is analogous to the Bentham’ s panoptic (Vaucheya, 1987). It was generalized around the 80’ s, after the defeat of the “free radios”, or “communities radios” of “associative radios”. They were replaced by networked commercial radios. All the room was taken by commercial chains or State radios. At the same time many public places were sonorized.

Here, the schema is an arrow. The signs (audio) go from the emitter to the receiver. They are arbitrarily chosen. There are no means to get rid of them. One is obliged to listen to them. One can argue that the arrow corresponds to technical characteristics. Of course, the sound goes in one direction, from the source to the place where it is listened to. But more interaction is possible. It is the theory of the specialist of media Pierre Schaffer, who presents the communication allowed by media as a triangle, not an arrow (Schaeffer, 1970). This theory is presented later in the paper.

Concerning the idea that technology generates solitude and confinement, it is disputable. Of course, many people watch TV or listen to radio, alone, during a long time. Today, the addiction concerns more the videogames. But people go outside their home, also. They crave some collective transes, that they find in more and more specialized places: dancing halls, concert halls, auditoriums, stadiums … Even in the villages, as soon as some kind of new entertainment becomes popular, people gather: dancing, singing, cooking, horse riding … (Fourquet, 2020). The same about solitude and confinement has been said about the car. Sure, a driver alone in a car is solitary and confined. But carpooling develops. In the European centers of large cities, one gets rid of the car. When people get acquainted for instance thanks to Internet or the social networks, they can meet using cars. The car is indispensable to the social life in the countryside.

4 THE SOUNDSCAPE

As it has been said, the soundscape is an urban legend. But it has three interesting characteristics that one will try to explain: presence, idealization and utility.

[2] The famous Franch economist Jean Fourastié (1907 – 1990) has described how, when he was a child, he listened to peasants working in the fields while singing together.

The soundscape has a presence.

After the French sociologist Baudrillard, there are in the society two kinds of processes: either extensive, either local and saturating (Baudrillarda, 1986). While the Bentham' s panoptic is an extensive process, there is also a local and saturating process: the soundscape. It is a kind of counterpart of the Bentham' s panoptic, hence its presence.

This presence is also shown thanks to a matrix of morphological analysis. The method of morphological analysis consists in analyzing a set of phenomena using a matrix which shows the characteristics of the diverse phenomena in the set: in lines, the phenomena, in columns, the criteria ¨E(characteristics). The method is useful to search for a new phenomenon, inside a set of phenomena already known.

One shows the Bentham' s panoptic and the soundscape ins this matrix:

	Extensive process	Local and extensive process	Real	Consumable
Bentham' s panoptic	✓		✓	
Soundscape		✓		✓

Fig 1. The matrix showing the characteristics of the two processes., the Bentham' s panoptic and the soundscape.

The two processes check different cases in the matrix.

The soundscape is the ideal counterpart of the Bentham' s panoptic. To use simple words, the soundscape is the opposite of the Bentham' s panoptic. The Bentham' s panoptic is imposed, comes from outside, is arbitrary, tiring and cannot be consumed. The soundscape is spontaneous, comes from inside and can be consumed (but it does not exist). It is pleasant, since it is the local sonic identity.

The soundscape is an idealization.

The soundscape is local, spontaneous, and consumable.

One knows that the cities develop by themselves, partly, and also are fashioned by forces outside them (globalization). So, the local autonomy is shaken up. It is the same for the villages. In the peri urban areas, the villages have deeply changed. For instance, the role of the farmers is declining (Charmes, 2019). The population shares its life between the next city and the village itself. When there were strong communities, workers belonging to the same large firm or the same economic sector, or fishers etc. there was a feeling of local autonomy. It was harmed by deindustrialization, changes in sectors not enough competitive or coping with new restrictive environmental rules etc. Some villages have overcome the crisis, and the population has increased. But it is thanks to newly arrived people who are very much linked to the next city. The decline of the local autonomy is visible when one considers radios. In the 70's and the 80's there was a move from pirate radios (using the hertzian spectrum illegally) to free radios (using the hertzian spectrum legally) to commercial radios (networked and privately owned) (Vaucheyb, 1987). So, when the local autonomy is declining, the soundscape corresponds to an idealized vision of the local communication, today.

The soundscape is useful.

The soundscape is useful, for commercial purposes. If you believe in the soundscape in Rio de Janeiro, New Orleans or Naples, you more easily buy music of samba, jazz, or Italian songs.

But it is more complex.

A soundscape can be transformed by many means, including AI, Artificial Intelligence. The time of Olivier Messiaen sitting in a field, by night, with his musical score and his pen, is over. A soundscape can be recorded thanks to sensors, then be changed and become a NFT (Not Tangible Token). A NFT is a file on Internet, which cannot be changed or imitated, with an owner, and is an asset (it can be bought or sold). Besides, there is folklore (originating from some soundscape). And, according to Constant Lambert, there is nationalist music (which uses themes coming from traditional songs or music) (Lambert, 1948). All these genres (soundscape, audio NFTs, folklore, nationalist music) allow mises en abyme and debates. This is required by the "game" in the cultural industry.

It is the same than when graphic arts are concerned. A century ago, the Franch painter Marcel Duchamp invented the "readymade", an object used in the every day life (like a shovel), but signed by the artist and produced in small series. Also, he painted a painting of the Joconde which was a joke. Do you believe that the end of the celebrated, unique artwork is a drama? No, it can be a joke, or even … a feast.

So, beside the celebrated, unique artwork (which can be seen in museums), there are copies in small series, copies in large series, luxury, kitsch …One can also mention hybridization (genres are hybridized). All these “genres” allow to attract the consumers. That these multiple tastes can be satisfied, exists, and is wanted and obtained.

After Baudrillard, the absurd and the catastrophe, are seductive (Baudrillardb, 1988).

Finally, the soundscape has its utility. But you cannot find it … Perhaps, it is in the archives of the ethnomusicologists, but it is impossible to find it if you do not belong to their milieu.

5 THE CHOSEN SOUND

After the French specialist of media Pierre Schaeffer, there is a triangle of the communication (not an arrow). A mediator negotiates with the emitter and the receiver, to adapt the messages sent to the needs and tastes of the receiver (Schaeffer, 1970). This triangle is shown on Fig 2.

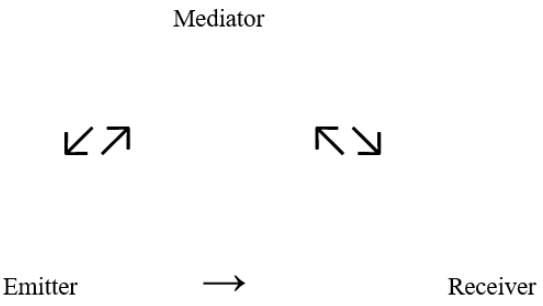

Fig 2. The triangle of the communication after Pierre Schaeffer.

Pierre Schaeffer proposes schemas a little more complex for the mainstream media (TV, radio) to take into account the differences (State owned, private). And there are also the Internet platforms like You Tube, Facebook … The turn has been made in the 80’s when the reality TV was invented. The message is so much adapted to the consumers’ s tastes that it is … himself. As Baudrillard has written, since the reality TV, you cannot challenge of criticize TV, since the TV … it is you. It is the chosen sound, opposed to the Bentham’ s panoptic (arbitrary sonorizing of a public place).

Of course, the contents are formatted to satisfy “targets”, that is to say consumers with tastes narrowly defined (genres, subgenres …). However, the dissatisfied or bored consumer can choose one among several responses:

- He can switch the genre where he chose what he consumed. The cultural industry delivers products classified in “genres” (Adorno, 2009).
- He can switch his tastes, which is usual in the “liquid life” (Baumann, 2013).
- Even, he can choose another kind of entertainment, including silence.

Of course, there is a pressure of the cultural industry on the consumer, since his tastes are tracked, influenced… It is what Baudrillard calls the “dictatorship of fashion” (Baudrillard, 1986). But in no way, it is the Bentham’ s panoptic. Even if it is the freedom of switching what one consumes to another kind of product, it is not the imposed sound of the Bentham’ s panoptic.

The idea of the soundscape triggers a dream: a sound which is yourself, that you can find easily, and which corresponds to a definitive taste … It is the idea of a consumption which is easy and according to definitive tastes. In reality, consumption implies the pressure of the cultural industry and the possible tiredness of the consumer.

6 CONCLUSION

According to the technological school, the social effect is encapsulated in the technology. The Foucaldian school takes them at their word, to criticize the arrow, which generates solitude and confinement. It is repressive, also. The two schools do not consider the contents themselves, very much. It is the same with Mac Luhan (“massage is the message”). At the opposite, Pierre Schaeffer, with its triangle of the

communication, is interested in the contents. The mediator negotiating with the emitting and the listeners, supervises the adaptation of the messages sent, to the needs and tastes of the listeners. This concerns the mainstream media (TV, radio), which have still a role. Concerning the Internet platforms, they allow many choices to the listeners and are prone to the cult of audience (the indicator being the number of clicks). If the consumer is dissatisfied or tired, he changes his choices. The soundscape is the dream of a communication which would be spontaneous, easy, and stable. It is also the ideal counterpart of the Bentham' s panoptic. Today, a surveillance society is a threat. Think of such software as Pegasus, Predator or Firstmile, which allow to take control of a smartphone, without the owner' s knowledge … The soundscape is reassuring.

An ultra-fast "natural history of the media" (pirate radios, free radios, commercial radios, mainstream media, state owned or privately owned, invention of the reality TV, Internet platforms) … shows us that local, autonomous, communication has been given up… The free radios in the 70 's have not lasted a long time. It generates a nostalgia which can explain the presence of the soundscape. Also, the soundscape could be explained by the nostalgia of this time, a century ago, when music was not a professionals' affair. According to Adorno, before the reign of recorded music, often music was performed by amateurs (Adorno, 2009).

Of course, the soundscape has existed in the culture of tribes, in the past. One can refer to Konrad Lorenz, again. According to him, the instincts of human beings are tamed, and either oppose one another either cooperate one with the other. There is a "parliament of the instincts", where the diverse instincts are in equilibrium, which explains a particular culture (Lorenz, 2018). But it is fragile. When the shock with the sturdy modern culture occurs, the tribal culture disappears. Perhaps there was a soundscape: a music performed with specific instruments, subtly linked to the characteristics of the environment where the tribe lived. But the soundscape disappears, also.

Now one discusses the topic of the soundscape and the cities.

In general, the residents wish silence. In Europe, several decades ago, laws on silence were passed. At the start, they were not really enforced, but finally, measures were taken: prohibition of traffic of trucks during the week ends, double glazed windows, noise protection screens alongside highways, attrition of the car in the centers of the large cities, soundproofing of buildings and flats, less noisy aircrafts … Today other measures are discussed: sound radars allowing to impose fines, prohibition of the traffic of motos during the night in the cities, paid parking for the motos with a thermal engine and free parking for the motos with an electrical engine, subsidies to buy a moto with an electrical engine…

To tell resident that one cannot complain with noise because it is the soundscape of the quarter would be a wrong argument and not welcomed. The statement "This soundscape … it is you" should be refused. We live in a competitive society in which people work or study before having a job, So, everybody needs rest. And the doctors agree …

And it is the same in the villages. In the villages in the peri urban areas, the governance is often that of a club (Charmes, 2019). Here people want heritage, security and silence. The village has to be the place where is the quality of life they want to benefit from. Often, they oppose new activities involving noise (mines, logistics …).

Is it that in the era of chosen sound all the problems are solved? Since the invention of headsets there would be no problem… Indeed, the people still like collective transes and feasts, in some quarters specialized in entertainment (cafés, cinemas, restaurants, spectacles …). Here, the residents complain with noise … Some cities, like Paris and Barcelona, want to attract tourists partying and, of course, have quiet streets, both. It is uneasy. In the countryside also, noisy meetings can occur when there are festivals which require nice décor. Even, festivals of pop music can occur in natural parks … Therefore, a stake of urban governance remains.

To conclude on the soundscape, it is a serious notion in some fields, like the soundscape under water that some experts analyse, or the soundscape in the nature, which is of interest for zoologists. The soundscape is a reference, with a presence, in culture. In urban planning, it seems that the notion has a negligible role. But it remains an urban legend.

In this society, there is an undisputable tribality. Some tribe can have its own soundscape (music, songs …). But it is a rite or a sign of recognition. It is transitory and local. It is not the "social marker" of the identity of a place. When there is some sonic scenography of the city, it is the same: it is not the marker of the identity of a place, but place branding. In the countryside a soundscape can be associated to an ecosystem (songs of

birds …) and be appreciated by some. There is no social identity, the soundscape is a characteristic of an ecosystem. Of course, the choice to preserve it is social, but it is more a stake concerning the global society, than a question of identity.

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Ageing Smart – Digital Instruments in a Municipal Context: Data, Analyses and Strategies (not only) for Baby Boomers

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1 ABSTRACT

The project addresses the baby boomers born between 1955 and 1969. As they gradually enter retirement age, municipalities are required to create age-appropriate residential locations and supply structures. The project brings together spatial planning, infrastructural and supply-side approaches from the perspective of the "baby boomers" and the municipalities. The aim is to develop a data-supported decision support system (DSS) that serves as a decision-making aid for public actors in their planning processes. The research project focuses on three fields of investigation: Residential locations and the associated requirements for opportunities in the residential environment and mobility, behaviour with regard to leisure and recreational activities and the provision of medical and related health infrastructures..

Keywords: decision support system, local infrastructures, municipalities, babyboomer, digital instruments

2 BACKGROUND AND RESEARCH QUESTIONS

The number of papers that emphasise digitalisation and artificial intelligence in the context of demographic change has increased significantly in the last 5-10 years. However, the debate has focussed on technical assistance systems and the need for care (cf. aal-deutschland.de). We are pursuing a different goal here: we are not focussing on the individual, but rather on supporting stakeholders who are responsible for infrastructure and services close to home in order to help maintain and safeguard the quality of life of the cohort of babyboomers in particular. A systematic analysis of supply and demand in seven municipalities from three spatial types (urban, suburban, rural) leads to the development of a data-based decision support system for local and regional stakeholders. We are combining research strands from various disciplines from a practice- and technology-orientated perspective.

The babyboomer cohort comprises almost a fifth of the German population, but little is known about their social situation, mentalities and behaviour (Nassehi 2019, Körber-Stiftung 2020). In the next ten years this cohort (born between 1955 and 1969, more than 1,1 million births each year), will enter retirement age. Changes in people's behaviour and demands on residential locations are assumed to take place with this fundamental change in the lifecourse. As long as these older adults do not continue working, individual time budgets and mobility patterns are changing radically; activities that were previously assigned to "recreation" and "leisure" (e.g. playing sports, shopping, excursions, basic supplies) determine everyday life. A change of residence might be desired or necessary, mainly for cost reasons or due to a lack of suitable opportunity structures. This biographical transition is of particular importance in terms of spatial planning, Municipalities are facing a variety of socio-spatial challenges, e.g. for healthcare provision, community acctivities and age-appropriat leisure facilities. The spatial behaviour of this generation - with its individualised and diverse lifestyles - has hardly been researched and can therefore hardly be foreseen.

On the other hand, the social and health infrastructures as well as infrastructures and public and private services are undergoing a profound restructuring via digitalisation.

The existing system is being called into question and new forms of services such as online administration, online shopping as well as telemedicine become more selfevident. The regional and municipal authorities responsible for spatial planning and services of general interest are facing onsiderable challenges. Following research questions shall be answered:

Which services do babyboomers require at the municipal level in which analogue-virtual interlinking, and what effects can digitalisation have on municipal infrastructures and services in the future?

How can social and spatial characteristics and their interactions be mapped in an interactive decision support system (DSS) in such a way that local actors in urban, suburban and rural areas are supported in their

strategic decisions on infrastructures and services specifically for the babyboomer cohort entering retirement age?

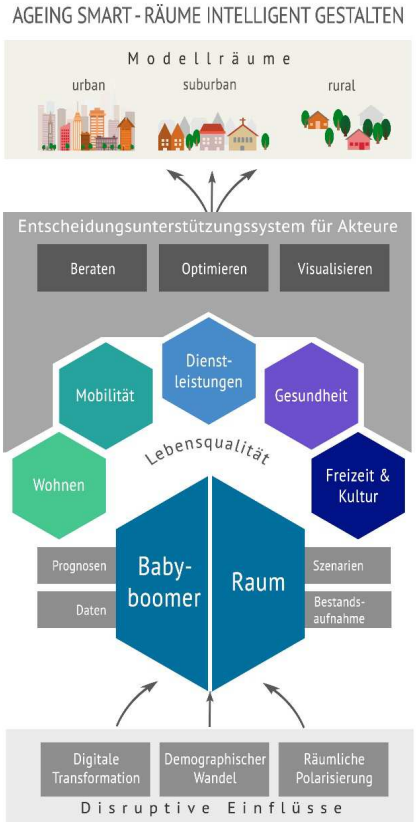

Fig. 1: Approach of the project "Ageing Smart – Designing spaces intelligently"

How can complex mathematical models based on uncertain amounts of data be handled theoretically and algorithmically in such a way that socio-spatial questions can be answered in the form of an interactive DSS and decision-making processes can be optimised at local level?

And which artificial intelligence (AI) technologies can be used sensibly and transparently?

3 OBJECTIVES AND FIRST RESULTS

The central objdective is to be able to show model-based solutions for selected municipalities from the three spatial types urban, suburban and rural and thus prepare decisions in order to improve urban structures, residential locations, infrastructures and services in line with demand. Based on different criteria, the following municipalities were chosen:

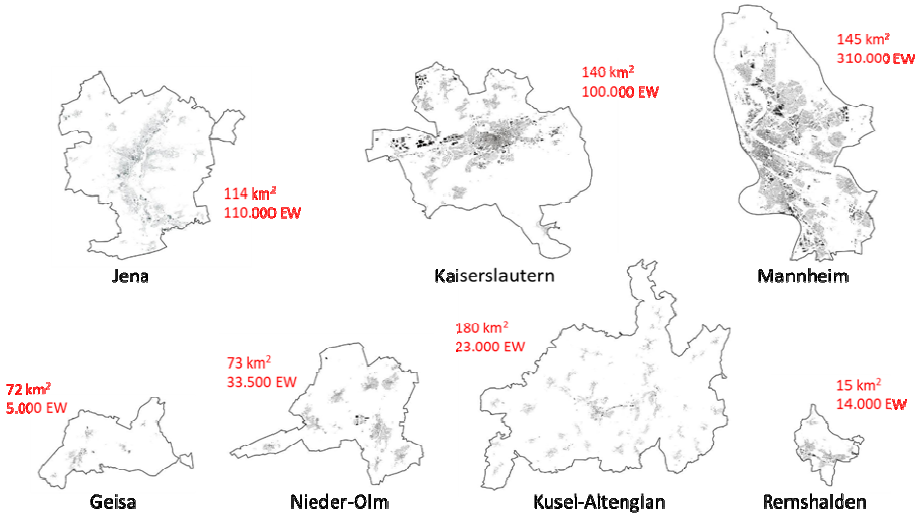

Fig. 2: Comparison of the settlement structures of the seven model municipalities.

All of the municipalities prioritised have agreed to participate in the project (see Fig. 2). These are: Kaiserslautern (RLP), Jena (TH), Mannheim (BW), Remshalden (BW), the municipality of Nieder-Olm (RLP), the municipality of Kusel-Altenglan (RLP) and Geisa (TH).

The research project is based on the integration and processing of a large number of different and sometimes complex data bases (including population data, cadastral data, localisation of infrastructures) using algorithmic methods of mathematics. In the context of the transition of babyboomers into retirement age, the focus is on the following areas:

- the development of urban structures and residential locations, e.g. the monofunctional residential areas of the 1970s and 1980s, but also the city centre districts as potential migration destinations for this cohort,
- locations, size and characteristics of community, leisure and recreational facilities in terms of demand and accessibility, but also taking into account local climatic and air quality conditions,
- healthcare, general practitioner care; taking into account hybrid service models that include mobile and digital services (telemedicine, video consultations, e-health systems, etc.) in addition to stationary facilities such as medical centres,
- the provision of cultural facilities, taking particular account of the dynamically developing demand and the high mobility and individuality of the baby boomer cohort,
- local public transport, which is coming under pressure to adapt due to the shift in commuter flows on the one hand, and new solutions on the other, and
- social situations, lifestyles and lifestyles of babyboomers in these three spatial types.

The household composition according to age and spatial differentiation is analysed by the sociological team. Household size decreases with increasing age, as children are more likely to have moved out of the parental household (Table 1). Household size is smaller in eastern Germany than in the western states. Children were born earlier here and therefore set up their own households earlier. There are more one-person households in cities; two-person households are mainly found in suburban and rural areas. Households with four people are more common in rural areas and large families in suburban areas. However, there is no clear allocation of families to suburban or rural areas, they live in cities to the same proportion.

			1955-1969 (Babyboomer)									
Size of House-hold	BRD	Born 1950 - 1954	1955 - 1959	1960 - 1964	1965 - 1969	Baby-boomer	West	East	Urban	Sub-urban	Towns in rural areas	Vill age s
1	43	38	35	33	32	33	32	40	40	27	34	22
2	33	55	52	41	25	40	40	43	35	45	39	54
3	12	6	9	15	20	15	15	12	13	14	18	14
4	9	1	3	8	17	9	10	4	8	11	6	8
5 +	3	0	1	3	6	3	3	1	3	3	4	2
n=	19027	1620	2002	2078	2541	6621	5079	1542	2842	2182	1299	298

Table 1: Household size by age group, baby boomers, West-East Germany and settlement structure (in %).

With regard to housing, more than half of baby boomer households are owner-occupiers, with the older cohorts (born 1955-1959) more likely to be owners than the younger cohorts (58% compared to 54%). In the West, the ownership rate is almost 10 percentage points higher than in the East, but even in the East, the rate in this cohort corresponds to the overall German level (58% compared to 47% in East Germany; FRG as a whole: 46%). In rural areas, almost three quarters of households own their own home.

Besides these illustrative results of sociological analysis, the author would like to draw attention to the following main areas of work:

- In addition to local geodata, small and micro-spatial data well below the neighbourhood level are processed (grid-based locations 100x100 metres in focus, e.g. location or statistical information in a hectare grid or finer, network and accessibility analyses). Creation of a list of quality of life

indicators from everyday goods (bakeries, butchers, drugstores and supermarkets) and green spaces (parks, squares, open green spaces and forests) and analysis of these using an internally developed evaluation procedure for availability, accessibility and diversity (Bielik u.a. 2019). Visualisations (visualisation, methods in planning: Berchtold and team (dvmp))

- Development of a mathematical model (see Laporte, u.a. 2015; Jena u.a. 2016; Schäfer u.a. 2020), which allows a time-dependent, intermodal accessibility analysis of the POIs in the model municipalities based on real timetable data, with the possibility of freely selecting numerous parameters to enable a target group-specific analysis. Population data based on the 2011 census is spatially localised so that weighting is also possible. (Mathematical optimisation: Ruzika and team)
- Development and implementation of several algorithms for calculating hiking routes: Based on existing hiking trails, alternatives are determined which are more suitable from a health perspective (isoprene exposure). (Optimisation, together with Physical Geografy: Henninger and Team)
- Current theoretical research focus is the integration of intermodal accessibility into mathematical location planning. (Optimisation; see Figure 3)
- In the eyes of many, green infrastructure plays a decisive role in the evaluation of a place to live (Henninger, Weber 2020). Urban areas with limited open spaces are increasingly seen by many people as a burden on health. Empirical surveys have shown that the general state of health of respondents whose homes were within a radius of 1 km to 3 km of the nearest green space was consistently positively influenced. Such results are particularly significant for older people (Wagner, Kuttler 2014). One research gap that the Ageing Smart project aims to fill is the question of whether the available retreat areas can be used by every group of people depending on the meteorological conditions.Development of a hiking trail isoprene cadastre using the example of the Kaiserslautern study area and transfer to the city of Jena. (Physical geography: Henninger and team and optimisation). Research into the relevant indicators (e.g. the allergy potential of trees, shading) to check the transferability of the chosen approach. Revision of the digital tree cadastre for Kaiserslautern (PhysGeo, DFKI)

- Studies on services of general interest have not yet made it clear how offers and approaches at municipal level for securing and expanding services of general interest are assessed. This project aims to answer the research question of how the choice of location of service providers (doctors, physiotherapy practices, pharmacies, etc.) can be influenced by the municipalities and which location factors are relevant for the most important service providers (especially doctors). We carried out structural analyses in the model municipalities and determined small-scale data on healthcare provision. Planning, implementation and initial evaluation of the survey on healthcare provision. (Regional development: Mangels, Stieving)

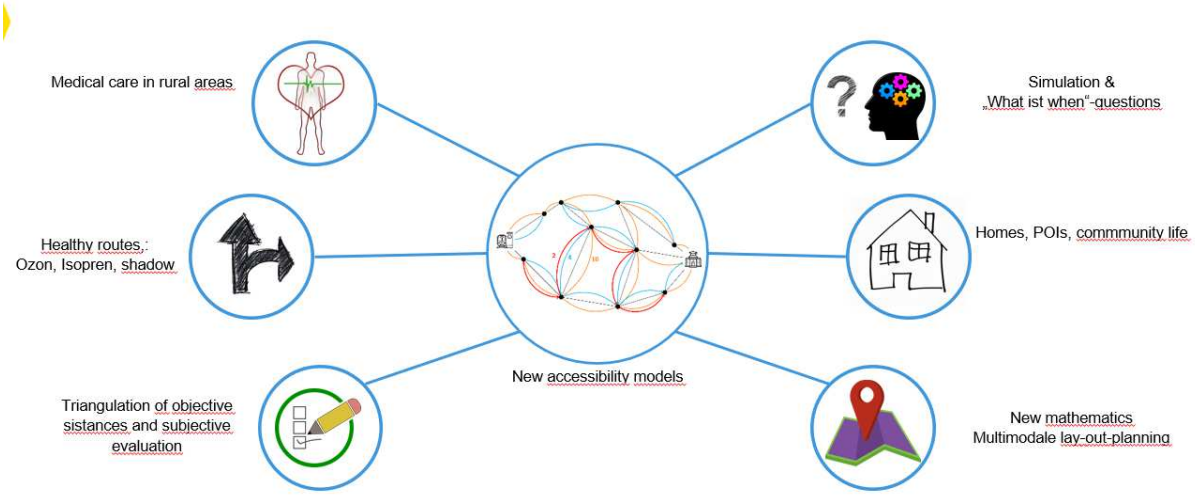

Fig. 3: Interdisciplinary use of the accessibility models; Design: Stefan Ruzika, Otimisation.

- One task is to quantify the concept of the 15-minute city in order to be able to carry out the accessibility analyses clearly and transparently. This also includes the identification of relevant POIs. Investigation of what accessibility is appropriate for infrastructures in terms of the 15-minute

city and how this can be guaranteed and improved. Selection of urban structure types as a spatial reference level; mapping of the urban structure types of the model municipality Jena in GIS and characterisation with profiles. The model municipality Kaiserslautern will follow as soon as the required data is available. (Urban planning: Kurth, Schittenhelm)

- Financing basis: effect of changes in population size and age structure on the municipal share of income tax; financing requirements: demand in the care sector) for subsequent processing using simulation techniques (economics: Junkernheinrich, Hestermann)
- Development and expansion of the "metadata tool" as a catalogue for data used or generated in the project, as a basis for quality management, transparency and explainability of the DSS. Processing and analysis of various data with the help of AI processes, including floating car data to extract information on mobility behaviour.(DFKI: Memmel, Meyer)
- Organisation of workshops in the model municipalities and initial consolidation of results (IESE: Berg and team)
- Development of priorities for the visualisation of municipal and research data (overall project) in order to design basic functionalities of the DSS in the area of data management and data visualisation (IESE; dvmp)
- Work of the data commission, which defines data-related processes and tools, specifies responsibilities and thus creates the framework conditions for sustainable and efficient data utilisation. (DFKI: Memmel, Meyer; urban sociology: Hartung; data, visualisation, methods in planning: dvmp)
- Demographic change is a global phenomenon that affects a large number of countries worldwide. Japan in particular, with its massive ageing population due to low birth rates and restrictive immigration policy, is regarded as a pioneer in the development of policies and strategies for dealing with demographic change. In other countries, such as the USA, the issue has only been discussed in the last decade, but here too demographic change will have a massive impact on society in the future (Henderson u.a. 2017). The collection of relevant examples of existing decision support systems used in spatial planning is in progress. Case study surveys with trips to the USA, Finland and Japan are conducted (site visits, expert discussions, interviews and analysis of statistical data) (International Planning Systems: Pallagst and team)

The networking of mathematics, computer science, social sciences, and spatial and environmental planning opens up new interdisciplinary perspectives in basic technical and mathematical research. The DSS to be developed will initially bring together a wide range of existing data sets of different origin and resolution (e.g. spatio-temporal settlement structure data, small-scale socio-demographic data from the registration system, statistical and socio-economic data) according to the classical model, develop innovative forms of visualisation for this purpose and provide the respective user with a broad overview and points of comparison to which he can relate his own situation. In addition, numerous mathematical application areas (such as location, layout or route planning) in the context of an ageing society are characterised by data-based, behaviour-oriented, dynamic and multi-periodic aspects. The aim is to depict these in suitable mathematical models and to show the decision-maker alternative courses of action obtained through optimisation processes in a DSS. If possible, demonstrably good solutions should be calculated so that the quality of the various decisions can ultimately be quantified and weighed up.

As the DSS envisaged in Ageing Smart is to be used in contexts that will have a direct influence on the way people live, the topics of ethics, transparency and explainability play a special role. The discipline of machine ethics is concerned with the question of how principles of ethical behaviour can be applied to the assessment of the "actions" of a machine and its design (on the fundamental philosophical questions of machine ethics. Such ethical questions are already highly relevant today and are even more so in the field of self-learning (Misselhorn 2028) systems. A further step is to analyse the repercussions of technical systems on people's social actions and on local governance structures, both of which are areas that have hardly been researched or predicted to date (Batty 2018).

4 CONCLUSION

With the central objective of developing a decision support system to optimise infrastructures and services for the baby boomer generation, the "Ageing Smart - designing spaces intelligently" project has a high level of social relevance. The DSS is intended to help local stakeholders from politics and administration to justify strategic considerations on location issues on the basis of data, to react safely to risky developments and to plan for the long term (housing, services, sport, recreation, health). During the project, the significance of the tool is continuously analysed in regard to ethical consequences. The iterative approach to developing the DSS and data-driven scenarios in workshops at local level is useful to further develop the understanding of complex interactions between physical and lifestyle aspects. Not only are services and infrastructures identified, but priorities and policy contexts will be considered. We hope to reduce the widespread scepticism towards mathematical models and data-driven decisions in municipalities.

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Die Diskrepanz zwischen Anspruch und Wirklichkeit: Wie gestalten wir intelligente Städte und Regionen der Zukunft kompetenzorientiert durch vernetztes Arbeiten?

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1 ABSTRACT

Der Beitrag beschäftigt sich mit der Frage einer ganzheitlichen Integration von smarten Projekten in die verwaltungsbezogene Aufgabenerfüllung am Beispiel der Metropolregion Rhein-Neckar. Die Ausgagsbedingungen mit vielfältigen Einzelprojekten und Maßnahmen bedient zwar erkannte Bedarfe in einer bundesweit vorbildlichen Art und Weise, eine Verknüpfung singulärer Zielsetzung in ein vernetzes Umsetzungskonzept bleibt aber weiterhin eine Herausforderung mit Bildungsbedarfen der Akteure.

Die Ziele der Betrachtungen liegen daher in der Fokussierung auf eine erfolgreiche Transformationsstrategie, die darin verankerten digitalen Lösungen, als auch die Weiterentwicklung digitale Kompetenzen unter den politischen-administrtiven Voraussetzungen.

Die Betrachtung basiert auf bisherige Arbeiten in Bezug auf ein Spannungsverhältnis zwischen den verfügbaren Ressourcen und den wachsenden Aufgaben bei Staat und Verwaltung. Die gegenwärtige Situation im föderalen Geflecht Deutschlands verdeutlicht, welch unverzichtbare und systemrelevante Bedeutung die Handlungsfähigkeit von Staat und Verwaltung einnimmt. Die Gestaltungs- und Vollzugsaufgaben auf regionaler Ebene wird hierbei insbesondere betrachtet.

Der Ansatz basiert auf einer semi-strukturierten teilnehmenden Beobachtung durch die Autoren. Qualitative Einblicke in die Praxis und abstrahierte Erkenntnisse anhand eines Fallbeispiels im Bereich digitaler Kompetenzentwicklung dienen als praktische Empfehlungen zur weiteren und damit ergänzenden Vertiefung und Erweiterung der Erkenntnisse

Die Erkenntnisse betreffen die Neugestaltung von Städten und Regionen und eröffnen weitreichende Möglichkeiten für die Integration von Gesellschaft und Wirtschaft in Planungs- und Reformprozesse durch Änderungsvorhaben zur Optimierung des Zusammenlebens im öffentlichen Raum durch smarte Services.

Die Bestrebungen hin zu einem digitalen Staat und smarten Kommunen sind deshalb wichtige Implikationen in die staatliche Leistungs- und Zukunftsfähigkeit, um im internationalen Vergleich wettbewerbsfähig zu bleiben und den Wirtschaftsstandort abzusichern.

Als Mehrwert liefert der Beitrag Ankünpfungspunkte für eine erfolgreiche Transformation und einen nachhaltigen Kompetenzaufbau von intelligenten Städten und Regionen im Verbund der Stakeholder mit verbindenden Elementen vernetzten Arbeitens.

Keywords: MOOCs, Kompetenzentwicklung, Nachhaltigkeitsmanagement, digitale Transformation, politisch-administratives System

2 HINFÜHRUNG ZUM THEMA

Alle Staaten stehen vor zahlreichen Herausforderungen und tiefgreifenden Veränderungen, die erhebliche Auswirkungen auf den Alltag der Menschen, die Gesellschaft sowie den Wohlstand haben. Durch die aktuellen Krisen (u.a. COVID-19-Pandemie, Klimawandel, Fachkräftemangel oder Migration) und die anhaltenden Konflikte in Europa, befindet sich die Weltgemeinschaft zunehmend im Handlungsdruck zur dynamischen Veränderung. Die Neugestaltung von intelligenten Städten und Regionen eröffnet umfassende Möglichkeiten für die Gesellschaft, die Verwaltung und die Wirtschaft. Sie ermöglicht nicht nur die Optimierung von Prozessen, sondern erleichtert auch das Zusammenleben nachhaltig. Die gegenwärtige Situation verdeutlicht, welch unverzichtbare und systemrelevante Bedeutung die Handlungsfähigkeit von Staat und Verwaltung einnimmt. Obwohl eine digitale Verwaltung vor mehreren Jahren noch als Kür betrachtet wurde, gehört sie heute zur Pflicht eines zukunfts- und leistungsfähigen Staates, um gesellschaftliche Herausforderungen bewältigen zu können. Die Bestrebungen hin zu einem digitalen Staat sind deshalb wichtige Investitionen in die staatliche Leistungs- und Zukunftsfähigkeit, um im internationalen

Vergleich wettbewerbsfähig zu bleiben und den Wirtschaftsstandort abzusichern. Die digitale Transformation der öffentlichen Verwaltung ist daher mehr als nur eine Neugestaltung. Dennoch muss das vorhandene Potenzial im Bereich der Digitalisierung von Staat und Verwaltung vollumfänglich ausgeschöpft werden. Für unseren Staat bedeutet die gegenwärtige Entwicklung, dass wir dringend sowohl in digitale Verwaltungsleistungen als auch in den Infrastrukturausbau investiert müssen. Die Verschleppung von Digitalisierung kann eine Gefährdung für die Demokratie sein.

3 NACHHALTIGE TRANSFORMATION VON STÄDTEN UND REGIONEN

Die Sustainable Development Goals (SDGs) sind eine Sammlung von 17 globalen Zielen, die von den Vereinten Nationen entwickelt wurden, um bis 2030 eine nachhaltige Entwicklung auf wirtschaftlicher, sozialer und ökologischer Ebene zu fördern. SDG 11 konzentriert sich speziell auf nachhaltige Städte und Gemeinden. Ziel ist es, Städte inklusiv, sicher, widerstandsfähig und nachhaltig zu gestalten.

Um SDG 11 zu erreichen, müssen Städte Maßnahmen ergreifen, um slumartige Bedingungen zu verbessern, den Zugang zu sicherem und bezahlbarem Wohnraum zu fördern, den öffentlichen Verkehr auszubauen und Grünflächen zu schaffen. Die Förderung von nachhaltiger Stadtplanung und -entwicklung ist entscheidend, um Ressourcen effizient zu nutzen und die Lebensqualität der Bewohner zu verbessern.

Eine erfolgreiche Umsetzung von SDG 11 trägt nicht nur zur Verbesserung der Lebensbedingungen in Städten bei, sondern hat auch positive Auswirkungen auf andere SDGs, wie z.B. Armutsbekämpfung (SDG 1), Geschlechtergleichstellung (SDG 5) und Klimaschutz (SDG 13). Durch die Schaffung nachhaltiger Städte wird eine integrative Entwicklung gefördert, die den sozialen Fortschritt, wirtschaftliches Wachstum und Umweltschutz miteinander verbindet. Dies zeigt die vernetzte Natur der SDGs und die Notwendigkeit einer gemeinsamen Anstrengung, um eine nachhaltige Zukunft für alle zu gewährleisten.

3.1 Digitale Transformation von Staat und Verwaltung

Auch die Digitalisierung der öffentlichen Verwaltung gewinnt dabei zunehmend an Bedeutung. Im Koalitionsvertrag der Bundesregierung spiegelt sich die Bedeutung und Dringlichkeit wider, den Staat zu modernisieren und den Aufbau digitaler Infrastrukturen zu beschleunigen. Deutschland muss handlungs- und leistungsfähig bleiben und vorausschauend für seine Bürgerinnen und Bürger arbeiten, so der Koalitionsvertrag der Bundesregierung (Koalitionsvertrag 2021, S. 8). Ziel ist es, dass mehr Transparenz und Teilhabe in Entscheidungen geboten wird, sodass das Leben der Menschen durch eine digitale Verwaltung erleichtert wird.

Obwohl eine digitale Verwaltung vor mehreren Jahren noch als Kür betrachtet wurde, gehört sie heute zur Pflicht eines zukunfts- und leistungsfähigen Staates, um gesellschaftliche Herausforderungen bewältigen zu können. Der digitale Wandel ist mehr als nur analoge Vorgänge „ein zu eins“ in Bits und Bytes zu übertragen (vgl. Martini, 2018, S. 13). Aktuell arbeiten alle Staaten mit Hochdruck daran, dass Verwaltungsleistungen digital verfügbar sind, die europäischen Staaten die Anschlussfähigkeit an den europaweiten digitalen Zugang zu Verwaltungsleistungen (Single-Digital-Gateway) sicherstellen und damit die EU-Verordnung (SDG-VO) fristgerecht erfüllen.

In den vergangenen Jahren haben Nachhaltigkeit und Digitalisierung gleichermaßen an Bedeutung gewonnen und sind zu vielschichtigen Schlüsselbegriffen des gesellschaftlichen Wandels geworden. Beide Konzepte beziehen sich auf große Transformationsdynamiken, die für moderne und digitale Gesellschaften scheinbar unvermeidlich sind. Obwohl es umfangreiche Forschung zu den Themen Nachhaltigkeit und Digitalisierung gibt, ist die Forschung nicht zusammenhängend, die sich mit beiden Phänomenen als übergeordnetem Gegenstand befassen. Diese Tatsache ist überraschend, da Technologie im soziologischen und gesellschaftlichen Diskurs über Nachhaltigkeit von Städten und Regionen eine systematische Rolle spielt. Digitale Technologien weisen zweifellos einen gesellschaftlich transformatorischen, wenn nicht sogar disruptiven Charakter auf bei der nachhaltigen Entwicklung (vgl. Lenz et al., 2023, S. 2)

Die Digitalisierung bietet vielfältige Möglichkeiten, die nachhaltige Entwicklungen in Städten und Regionen voranzutreiben. Die Agenda 2030 der Vereinten Nationen definierte 17 Ziele für nachhaltige Entwicklung (SDGs). Die Nachhaltigkeitsstrategie der Bundesregierung orientiert sich an sozialen, ökologischen und wirtschaftlichen Zielen im Rahmen des Dreisäulenmodells. Die Verknüpfung von Nachhaltigkeit und Digitalisierung ist von entscheidender Bedeutung für die Erreichung des Nachhaltigkeitsziels 11 für

nachhaltige Innenstädte und Regionen. Die fortlaufende Anpassung der Nachhaltigkeitsstrategie der Bundesregierung und die Integration von Technologien können Ressourceneffizienz steigern, den Verkehr nachhaltig optimieren und schlussendlich die Lebensqualität in Städten und Regionen verbessern. Durch die Integration von Digitalisierung in nachhaltige Konzepte können konkurrierende Ziele besser ausbalanciert und umgesetzt werden. Daher ist es laut Lätzel entscheidend, frühzeitig sozial-ökologische Chancen und Risiken der Digitalisierung zu identifizieren. Es geht dabei nicht darum, vorhersagen zu wollen, wie die Zukunft sein „wird", denn die Zukunft ist prinzipiell offen und gestaltbar. Wir müssen uns vielmehr fragen, welche Zukunft wir wünschen und wie diese realisiert werden kann. Dafür bedarf es unter anderem einer intensiven sozial-ökologischen Forschung, die das Thema Digitalisierung als eines der Kernthemen unserer Gegenwart ernstnimmt (vgl. Lätzel, 2020, S. 11ff.).

Die Transformationsdebatte und auch die Transformationsforschung sind primär auf eine ökologische Dimension (Klimawandel, Biodiversitätsverlust) ausgerichtet mit dem Ziel, Entwicklungschancen der Gegenwart für zukünftige Generationen zu bewahren (Generationengerechtigkeit). Diese Perspektive ist eurozentrisch geprägt und macht soziale und globale Ungleichheiten unsichtbar. Eine globale Transformation zur Nachhaltigkeit kann laut Bauriedl et al. (2021) aber nur gelingen, wenn sie sowohl eine Generationengerechtigkeit (zeitliche Dimension) als auch eine internationale Gerechtigkeit (räumliche Dimension) und intersektionale Gerechtigkeit (soziale Dimension) verfolgt. In Bezug auf lokale Erfordernisse lässt sich im Sinne einer effektiven Umsetzung eine weitere, technische Dimension einbringen, da der Transfererfolg von Maßnahmen verantwortlich für Wirkungen in der Gesellschaft sind (vgl. Abbildung 1). Zur Vermeidung von Transformationskonflikten und anhaltender Nicht-Nachhaltigkeit muss dementsprechend aus unserer Sicht die Schnittstelle dieser vier Dimensionen stärker im Fokus stehen.

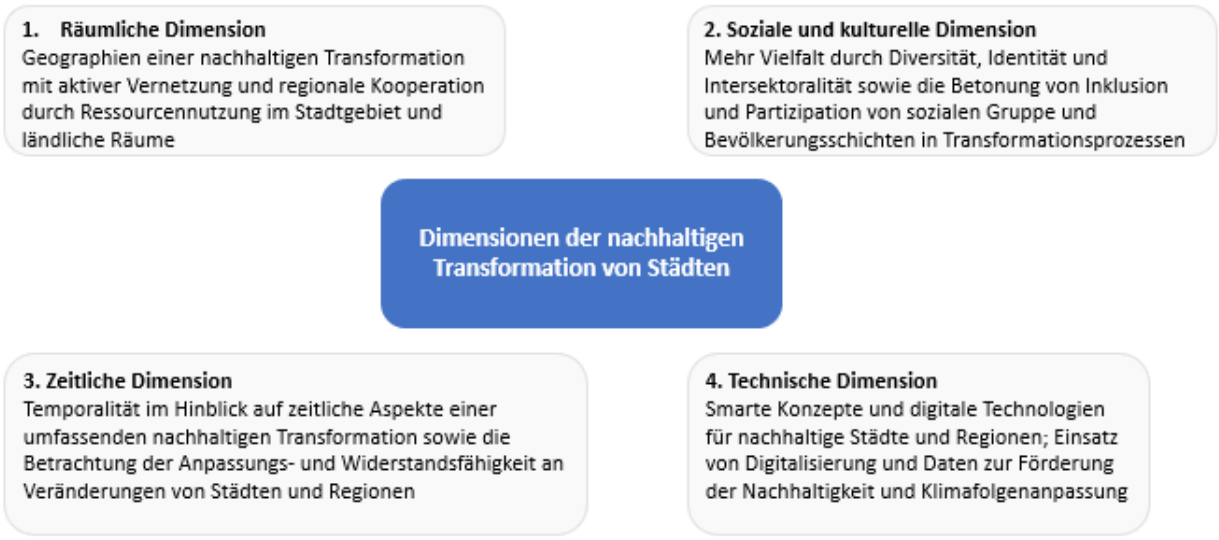

Abbildung 1: Dimesionen der nachhaltigen Transformation von Städten und Regionen. Quelle: Eigene Darstellung in Anlehnung an Bauriedl et al. (2021), S. 40

Das mit Wirtschaft, Wissenschaft und Zertifizierungsagenturen entwickelte Vorgehensmodell richtet sich in der Analyse auf die Etablierung einer transparenten Dialogkultur, indem eine Vielzahl an Vorgaben (etwa die 17 SDGs der Agenda 2030 inkl. der 169 Unterziele, ISO 26000, ISO 14001, ISO 50001, GRI Standards u. v. a.) für die Unternehmens- bzw. Organisationspraxis anwenderfreundlich heruntergebrochen wird. Die Kategorien der nachhaltigen Unternehmensführung im Denken, Handeln, Kommunizieren und Messen der Leistungserbringung werden entsprechend der drei Handlungsfelder bewertet. Insofern kann eine Anwendung des Zyklus aus Zieldefinition, Maßnahmenumsetzung, Wirkungsanalyse und Gegenmaßnahme in allen Größenklassen von Unternehmen und Organisationen verwirklicht werden.

Aufgrund standardisierter Anforderungen im betrieblichen Umweltschutz sowie den ethischen Handlungsgrundsätzen entsprechend des CSR-Ansatzes (Corporate Social Responsibility) sollen soziale wie ökologische Aspekte der innerorganistorischen Arbeitsbedingungen geleitet werden. Zudem sollen für alle Branchen und Unternehmensgrößen die Entwicklung innovativer Lösungen unter gemeinnützigen Gesichtspunkten ein höheres Gewicht zukommen zu lassen. Durch den grundsätzlichen Anspruch auf digitale Verwaltungsleistungen erhält die Digitalisierung in allen Bereichen Einzug und die Verwaltungen in

Deutschland stehen durch das Onlinezugangsgesetz (OZG) unter enormen Handlungsdruck. Während der Corona-Pandemie wurden in kürzester Zeit viele Angebote durch Staat und Verwaltung initiiert, die die Digitalisierung vorangetrieben und Bedeutung des Themas gesteigert haben. Demzufolge stieg auch die tatsächliche Nutzung digitaler Angebote in der Dach-Region (Deutschland, Österreich und Schweiz), insbesondere in Deutschland (vgl. Initiative D21 & Technische Universität München, 2020, S. 6). Befragte fordern aber von der Verwaltung, dass ihre Leistungen einfach und bequem erledigt werde können (Initiative D21 & Technische Universität München, 2023, S. 15-16). Die aktuelle Situation und Entwicklung zwingen den Staat zum Handeln, denn das Vertrauen in die Staaten sinkt erheblich.

Regionen können länder- und ebenenübergreifende Innovationsräume sein, um die nachhaltige Entwicklung von Städten und Regionen zu befördern. Diese bilden Schnittstellen zwischen verschiedenen Akteuren. Die Herausforderungen und Lösungen für nachhaltige Entwicklung enden nicht an Ländergrenzen zwischen Ländern, sondern Regionen können in der Lage sein, übergeordnete Ziele zu setzen, die auf eine grenzübergreifende Kooperation abzielen. Die Metropolregion Rhein-Neckar hat eine regionale Entwicklungsstrategie Vision 2025 ins Leben gerufen, mit dem Ziel, bis 2025 als eine der attraktivsten und wettbewerbsfähigsten Regionen Europas anerkannt zu werden. Um die Vision zu realisieren, wurden in der Metropolregion Rhein-Neckar verschiedene Handlungsfelder identifiziert, die gezielt Nachhaltigkeitsaspekte in Schlüsselbereichen wie nachhaltige und bedarfsgerechte Mobilität, Förderung regionaler Innovationen, Umsetzung der Energiewende sowie die Gestaltung der Bildung der Zukunft fördern.

Im Kontext dieser Handlungsfelder wurden diverse Projekte und Strategien in der Metropolregion umgesetzt. Beispiele hierfür sind ein Mobilitätspakt, der die Förderung nachhaltiger Verkehrsmittel beinhaltet, sowie eine Arbeitsmarkt- und Qualifikationsstrategie, die auf die Bewältigung demografischer Veränderungen abzielt. Zudem beteiligt sich die Region aktiv an staatlich geförderten Pilotprojekten, welche die Förderung von Digitalisierung und Innovation zum Ziel haben – wie mit dem Modellvorhaben „Kooperatives E-Government in föderalen Strukturen“ (vgl. OCED, 2023, S. 3).

3.2 Digitale Infrastrukturen für Smart Cities and Regions

Für Städte und Regionen der Zukunft sind die notwendigen Infrastukturen und die zielgerichtete Datenverfügbarkeit und -nutzung zunehmend erforderlich. Dies umfasst zum Beispiel für nachhaltige Innenstädte der Zukunft beispiesweise die Verbesserung der Mobilitätssystem oder die Beeinflussung des Klimawandels durch digitale Technologien.

Die unter dem Begriff "Smart City" bekannte digitale Erneuerung städtischer Einrichtungen ist bisher hauptsächlich von Angeboten und wirtschaftlichen Zielen der Digitalbranche bestimmt und weniger auf die diversen Bedürfnisse der Stadtbewohner abgestimmt. Aktuell tragen Smart City Strategien leider kaum zu größerer ökologischer Gerechtigkeit in urbanen Gebieten mit hoher Segregation bei (Marvin et al, 2018). Es besteht die Gefahr, dass durch die digitale Erneuerung in Städten soziale Ungleichheiten und Ungerechtigkeiten verstärkt werden. Für eine langfristig tragfähige digitale Veränderung ist es wichtig, das Gemeinwohl in den Vordergrund zu stellen. Dies sollte sich an den Wünschen und Möglichkeiten der Stadtbewohner orientieren und erst danach die zur Verfügung stehenden Technologien in Betracht ziehen. Für eine inklusive Smart-City-Strategie und Bürgerbeteiligung sind essenziell, dass die Bewohner an der Entwicklung und Implementierung digitaler Technologien beteiligt sind, einen gerechten Zugang zu digitalen Services haben und alle wichtigen Teile, Codes und Prozesse offengelegt werden. Dabei sollte die Erfassung und Kontrolle persönlicher Daten transparent erfolgen. Diese Ansätze von Smart Cities stehen stark im Kontrast zu den Geschäftsmodellen der Plattformökonomie und IT-Konzerne und können in der Realität vermutlich nur mit geeigneten Common-Code-Anbietern und vernetzter Softwareentwicklung von kommunalen IT-Abteilungen umgesetzt werden. (vgl. Kanning & Meyer, 2019, S. 9ff.).

Die zunehmende Urbanisierung und der fortschreitende Klimawandel stellen große Herausforderungen für die Städteplanung und -entwicklung von intelligenten Städten dar. Die Klimaerwärmung wirkt sich beispielsweise verstärkend auf die Hitzeentwicklung in städtischen Gebieten aus. Infrastrukturen und Daten haben eine große Bedeutung, um urbane Hitzeinseln zu bekämpfen. Sie ermöglichen eine fundierte Analyse der aktuellen Situation, die Identifizierung von Hitze-Hotspots, die Auswirkungen auf Menschen und Umwelt, die Entwicklung von effektiven Maßnahmen sowie das Monitoring und die Weiterentwicklung der umgesetzten Anpassungsmaßnahmen. Durch die sensorbasierte Erfassung von z.B. der Oberflächentemperatur, Lufttemperatur, mittlerer Strahlungstemperatur oder Feuchtigkeit in Kombination

mit der Windgeschwindigkeit, Bebauung und sozioökonomischen Daten in verschiedenen städtischen Gebieten, können Hitze-Hotspots identifiziert und kartiert werden. Es besteht zunehmend ein wachsendes Bewusstsein dafür, dass innovative Maßnahmen und Strategien erforderlich sind, um den Klimawandel zu begrenzen und um die Lebensqualität der städtischen Bevölkerung langfristig zu verbessern. In diesem Kontext können auch digitale Technologien maßgeblich zur Klimafolgenanpassung beitragen, indem Hitzteinseln auf einer Datengrundlage identifziert und innovative und nachhaltige Maßnahmen zur Anpassung an den Klimawandel umgesetzt werden.

4 DIGITALE KOMPETENZEN UND INNOVATIVE LERNFORMATE

In diesem Zusammenhang gewinnt auch die Förderung digitaler Kompetenzen und Mitarbeiterbefähigung an Bedeutung, da sie einen entscheidenden Beitrag zu einer nachhaltigen Entwicklung von Städten und Regionen leisten kann. Eine gegenwärtige Herausforderung ist, die Potenziale als Chance zu begreifen und die Potenziale der digitalen Transformation zu erschließen. Die kontinuierliche Weiterentwicklung und der Kompetenzaufbau umfassen die Fähigkeit und das Wissen, smarte Lösungen zu identifizieren und in der Praxis erfolgreich umzusetzen. Dabei bildet die Digitalkompetenz von Individuen einen integralen Bestandteil und sind eine grundlegende Voraussetzung (vgl. Tazir et al., 2021, S. 106)

4.1 Bildung für eine nachhaltige Entwicklung

Die Implementierung von Bildung für nachhaltige Entwicklung (BNE) an Universitäten beinhaltet unter anderem die Realisierung des nationalen Aktionsplans BNE in diversen Handlungsbereichen. Der Hauptfokus liegt dabei auf der Entwicklung von BNE-Kompetenzen in Politik, Zivilgesellschaft und Verwaltung durch koordinierte Qualifikationsprogramme und Faktoren, die ein "intelligentes Regieren" ermöglichen. Weitere wichtige Aspekte sind im Handlungsfeld III (diverse BNE-Wege) die Bereitstellung von unabhängigen Lern- und Lehransätzen zur Bewertung von Nachhaltigkeit durch die Zusammenarbeit kompetenter Dienstleister oder im Handlungsfeld V (Entwicklung transformativer Narrative für BNE), wo aktuelle gesellschaftliche Themen mittels Forschung und Lehre in gesellschaftlicher Verantwortung eine neue Perspektive erhalten.

Es ist notwendig, sich auf ganzheitliche Weise mit Nachhaltigkeit auseinanderzusetzen, um den sich dynamisch entwickelnden gesellschaftlichen Anforderungen im öffentlichen Bereich gerecht zu werden. Agile Netzwerke mit verschiedenen Akteuren aus den Bereichen Forschung, Wirtschaft und Zivilgesellschaft können dazu beitragen, „schwarmintelligente“ Ansätze zu nutzen und „smarte Lösungen“ für integrierte Nachhaltigkeit mithilfe von Informations- und Kommunikationstechnologien zu erarbeiten. Für die nachhaltige Aktivierung von kontinuierlichem formalem und informellem Lernen durch Technologieeinsatz sind überzeugende didaktische Formate notwendig. Diese sollten praxisnahe Kontexte nutzen, um sowohl inhaltliche als auch methodische Anforderungen durch Lernszenarien zu unterstützen. Wie die empirische Analyse von Dehne zeigt, fördern Online-Kollaborationsprojekte eine offene Bildungspraxis, die für diese Ziele notwendig ist. Dies ist jedoch hauptsächlich bei digitalen Lehr-Lernszenarien der Fall, die bisher nur in einzelnen Projekten umgesetzt wurden (vgl. Nisbet et al., 2019, S. 318ff.).

Es ist besonders wichtig, dass der öffentliche und gemeinnützige Sektor in Entwicklungspläne investiert, die auf kommunaler Ebene direkt spürbar sind. Ziel ist es, die digitale Transformation in nachhaltigen europäischen Regionen, unterstützt durch Beispiele aus Energiesektor, Gebäude- und Verkehrsmanagement sowie soziale Interaktion und Beteiligung, greifbar zu machen. Um dieses Potenzial zu nutzen, ist es erforderlich, dass Mitarbeiter auf verschiedenen Verantwortungsebenen systemisches Denken erlernen. Dies ermöglicht es ihnen, Optimierungspotenziale und Nachhaltigkeitskriterien im täglichen Arbeitsprozess zu erkennen. Digitale Tools und Dashboards können dabei helfen, die Belastung der Klimabilanz in öffentlichen Dienstleistungen transparent zu machen, auch wenn sie allein noch nicht ausreichen, um das Ziel vollständig zu erreichen. Seit Beginn der 2000er Jahre ist die digitale Transformation nicht nur in der Arbeitswelt, sondern auch in der didaktischen Gestaltung von Hochschullehre und Weiterbildungsangeboten allgegenwärtig. Sie ermöglicht eine Flexibilisierung und Individualisierung des Unterrichts, was insbesondere in der berufsbegleitenden Weiterbildung attraktive digitale Lernszenarien schafft (vgl. Kergel & Heidkamp-Kergel, 2020). Die Kombination von Online- und Präsenzunterricht (Blended-Learning) ist besonders effektiv, wenn organisatorische Strukturen vorhanden sind, die es ermöglichen, die Lernphase selbst zu bestimmen und gleichzeitig eine Kontrolle des Lernfortschritts und ein Feedback zu gewährleisten.

Die Wissenschaft stimmt weitgehend überein, dass die Nutzung digitaler Lehrformate eine Chance zur Stärkung der Lernorientierung bietet. Auf allen föderalen Ebenen von Bund, Ländern und insbesondere Kommunen fehlt es an digitalen Kompetenzen der Beschäftigten, um das Potenzial der Digitalisierung zu schöpfen. Das Faxgerät zur Meldung der Corona-Zahlen in den Gesundheitsämtern oder Formulare stehen symbolisch für die Verschleppung und Versäumnisse (vgl. Baldauf et al., 2022, S. 221).

Der Kompetenzaufbau ist nicht nur in individueller Hinsicht von Relevanz, sondern kann dazu beitragen, dass der Fortgang bei der Gestaltung von intelligenten Städten und Regionen schneller gelingt. Der Einsatz von digitalen Techologien und Lösungen erfordert mehr Investitionen in den Kompetenzaufbau. Angesichts des demografischen Wandels und Fachkräftemangels, müssen bei zunehmend wachsenden und neuen Aufgaben auch die Mitarbeiter befähigt werden. Es bedarf einer innovationsfähigen Verwaltung, die bereit und befähigt ist, neue Wege zu erproben und innovative Ideen anzugehen (vgl. Krause et al., 2023, S. 369).

Allerdings setzt eine auf "Learning-Outcome" abgestimmte Veranstaltung voraus, dass sowohl Lernende als auch Lehrende eine gemeinsame Verantwortung bei der Gestaltung des Lernprozesses erkennen. Statistisch auswertbare Teilleistungen sind nützlich, um den Lernerfolg oder Fortschritte in verschiedenen Kompetenzbereichen visuell darzustellen, was auch als "Learning Analytics" bezeichnet wird.

Ein signifikanter Fortschritt zeichnet sich in den technologischen Möglichkeiten zur interaktiven Gestaltung von Lehr-Lern-Beziehungen aus. Daher sollten sie früh in die didaktischen Überlegungen einbezogen werden. In der Vergangenheit konnten auf diese Weise Formate wie massive offene Online-Kurse (MOOCs), offene Bildungsressourcen (OER) oder Künstliche Intelligenz-gestützte Mensch-Maschinen-Interaktion identifiziert werden. Die Diskussion über digitale Kompetenzen ist in vollem Gange, jedoch ist unklar, welche Fähigkeiten und Kenntnisse damit gemeint sind (vgl. Krause et al., 2023, S. 13). Zumindest gibt es ein einheitliches Verständnis im Hinblick auf die Bedeutung von digitalen Kompetenzen. Befragte bewerten die Bedeutung von Kompetenzen bei Entscheidungsträger in der Verwaltung als die wichtigste Fähigkeit für Zukunft der Verwaltung (vgl. Hertie School of Governance/Wegweiser GmbH, 2021, S. 15).

4.2 Gestaltungspotenziale von MOOCs am Beispiel des eGovCampus

Zwei innovative Ansätze zur bedarfsorientierten Kompetenzentwicklung sind der KommunalCampus und eGovCampus, worüber Lerninhalte zur Stärkung digitaler Kompetenzen bereitgestellt werden (vgl. Baldauf et al., 2022, S. 222).

Im Rahmen des vom IT-Planungsrat geförderten Projektes „eGov-Campus” werden derzeit Massive-Open-Online-Courses (MOOC) entwickelt und umgesetzt, damit sich Lernende aus dem Bereich des öffentlichen Sektors weiterbilden können (vgl. Tannert et al., 2023, S. 101). Die jeweiligen Module werden von Entwicklerteams verschiedener Hochschulen eigenständig erstellt, sollen jedoch langfristig miteinander harmonisieren. Jedes Modul beinhaltet Lerneinheiten, sogenannte "Nuggets". Diese LE bestehen aus mit Folien hinterlegten und untertitelten Videovorträgen oder Audiobeiträgen. Ein Vergleich mit den sogenannten MOOCs (Massive Open Online Courses) verdeutlicht, dass die Instrumente, die für die Unterrichtspraxis am wichtigsten sind, in Metastudien oft nicht die stärkste Priorität genießen. Im Kontext intelligenter Nachhaltigkeitsbildung wird der grundlegenden Idee des kollaborativen Lernens durch vernetzte Lerngruppen eine größere Bedeutung beigemessen, was auch die Hochschulrektorenkonferenz (HRK) dazu bewogen hat, sich intensiv mit diesem Thema auseinanderzusetzen. (HRK, 2014).

Erfahrungsorientierte Formate, die sich mit der Verknüpfung von auf Echtzeitdaten basierenden OPEN Data-Analysen beschäftigen, gewinnen an Bedeutung, sofern ein akzeptables Maß an Anonymisierung gewährleistet werden kann, um die Anforderungen der DSGVO zu erfüllen. Sie tragen dazu bei, Lernzyklen anhand von praxisnahen Use-Cases zu entwickeln und Lernprozesse für die nachhaltige Entwicklung voranzutreiben. Die gewünschten Wirkungen "intelligenter Lehrkonzepte" treten auf, wenn praktische Methoden wie Nutzerstories und Prototyping mit den Erfolgsfaktoren aus Best-Practice-Beispielen für intelligentes Regierungshandeln kombiniert werden und so zu einem forschenden Lernen beitragen (vgl. Voß, 2018, S. 39). Neben den Video- und Audiobeiträgen stehen außerdem Transkripte zur Verfügung. Das Grunddesign und die Struktur wurden einheitlich für alle Module auf der Lernplattform eGov-Campus entwickelt (vgl. Tannert et al., 2023, S. 103-104).

Die Lerninhalte müssen bei einer rein digitalen Vermittlung so gestaltet werden, dass sie die Lernenden motivieren und nicht nach einem klassischen Muster. Vielmehr bedarf es Elementen zur Vor- und

Nachbereitung sowie der Möglichkeit zur Interaktion mit den Dozentinnen und Dozenten, jedoch nicht nur E-Learning-Angebote. Daran knüpft auch der KommunalCampus als Partnerprojekt mit einem Blended-Learning-Ansatz an.

Der Blended-Learning-Ansatz des KommunalCampus stellt einen entscheidenden Erfolgsfaktor dar, um digitale Kompetenzen auf kommunaler Ebene zu stärken. Die geschickte Verbindung von Online-Angeboten in der Vor- und Nachbereitung mit Live-Tutorien durch qualifizierte Dozenten, legt den Grundstein für einen nachhaltigen Aufbau von Kompetenzen. Gleichzeitig ermöglicht die Strukturierung der Angebote eine gezielte Zuordnung, sodass Mitarbeitende nicht mit Kursinhalten konfrontiert werden, die für sie wenig relevant sind. Ein standardisierter Ablauf gewährleistet zudem die nahtlose Integration der Weiterbildung in den beruflichen Alltag (vgl. Baldauf et al., 2022, S. 226).

Beide Projekte eGovCampus und der KommunalCampus nehmen eine wegweisende Rolle ein, indem sie innovative Bildungsansätze wie Massive Open-Online-Courses (MOOCs) und Blended Learning in den Fokus rücken. Dieser Beitrag beleuchtet die Bedeutung dieser Bildungsplattformen für die Förderung digitaler Kompetenzen auf kommunaler Ebene und deren entscheidende Rolle in der Gestaltung intelligenter urbaner Lebensräume. Die Integration von Themen Smart Cities/Regions auf dem eGovCampus und KommunalCampus eröffnet einen weitreichenden Zugang zu relevantem Wissen. Dieses Format ermöglicht es Mitarbeitenden in kommunalen Verwaltungen sowie Interessierten aus der Region, flexibel und ortsunabhängig an hochwertigen Kursen teilzunehmen. Die Breite und Vielfalt der angebotenen MOOCs unterstützen die individuelle Entwicklung digitaler Kompetenzen, die wiederum einen zentralen Faktor für die Transformation hin zu Smart Cities und Regions darstellen. Die Modularität der Bildungsangebote auf dem eGovCampus und KommunalCampus ermöglicht es, Lerninhalte individuell auf die Bedürfnisse und Interessen der Lernenden abzustimmen. Durch die Integration von innovativen Bildungsansätzen wie Massive Open Online Courses (MOOCs) und Blended Learning, legen diese Plattformen den Grundstein für eine zukunftsweisende Gestaltung von Smart Cities und Regions.

5 FAZIT

Die Zukunft von Städten und Regionen erfordert nicht nur einen modernen Staat und digitale Infrastrukturen für den Einsatz von smarten Technologien, sondern auch eine kontinuierliche Entwicklung digitaler Kompetenzen. Dieser Beitrag hebt die Bedeutung der digitalen Kompetenzentwicklung für die erfolgreiche Gestaltung von intelligenten Städten und Regionen hervor.

Um effektive und effiziente Nachhaltigkeit auf lokaler und regionaler Ebene zu gewährleisten, ist ein kooperatives und anwendungsbezogenes Bildungsprogramm erforderlich. Dieses muss die lokalen Wertschöpfungsprozesse einschließlich Wirtschaft, Wissenschaft, kommunale Entscheidungsträger und Zivilgesellschaft systematisch analysieren und die Auswirkungen auf die Klimabilanz und den CO2-Fußabdruck berücksichtigen. Darüber hinaus sollte es die Informationen visuell darstellen und transparent zur Verfügung stellen. Kommunen können in diesem Zusammenhang nicht nur als Koordinatoren für interne Weiterbildung agieren, sondern auch als zentrale Ansprechpartner für intelligente Vernetzung dienen. Für kleinere Kommunen könnte der Zusammenschluss zu regionalen Allianzen von Vorteil sein, um schnell adäquate Fähigkeiten zu entwickeln und Synergien mit anderen regionalen Akteuren zu nutzen.

Es ist wichtig, die Verwendung von dynamischen, medienunterstützten Lernumgebungen unter kritischen Evaluationsgesichtspunkten zu betrachten, um deren Mehrwert im didaktischen Design abzuwägen und die kollaborativen Lerneffekte für die Praxispartner verständlich zu machen. Hierbei wird eine fortlaufende Weiterentwicklung der Methoden durch Best-Practice-Ansätze angestrebt. Die Projekte eGovCampus und KommunalCampus treten als Pioniere auf, indem sie innovative Bildungsansätze wie Massive Open Online Courses (MOOCs) und Blended Learning integrieren. Diese Ansätze ermöglichen nicht nur einen flexiblen Zugang zu Wissen, sondern fördern auch einen nachhaltigen Kompetenzaufbau für intelligente Städte und Regionen.

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Exploring Consumer Adoption of Electric Vehicles in Japan: an Empirical Study

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1 ABSTRACT

In line with the Green Growth Strategy, Japan has actively pushed for the increased adoption of electric vehicles (EVs, PHVs, FCVs) aiming for their exclusive presence in new passenger car sales by 2035. However, Japan's progress in electric vehicle uptake lags behind other developed nations. Despite robust marketing efforts by both local and global automakers, Japanese consumers remain hesitant to embrace electric vehicles. This study conducts a pilot survey to gauge the demand for electric vehicles in Japan. Results indicate that respondents prioritize the country of manufacturer as the most crucial factor in their next passenger car purchase, followed by the car's drive type and cruising range. Price is considered the least influential factor. Notably, respondents place significant importance on domestic manufacturer and plug-in hybrid drive type. These findings offer valuable insights for academic research and policymaking to encourage broader electric vehicle adoption in Japan.

Keywords: Green Growth Strategy, Electric Vehicles, Carbon Neutral Society, Consumer Behaviour, Japan

2 INTRODUCTION

Recent advancements in Japan's automotive sector have been significantly influenced by the Green Growth Strategy initiated by the Japanese government. This strategy views the response to global climate change as an opportunity for industrial and socioeconomic transformation rather than a hindrance to economic growth (Cabinet Secretariat, et.al., 2021). Specifically, the Green Growth Strategy aims to reduce greenhouse gas emissions by 46% by 2021, relative to 2013 levels, in alignment with the country's carbon neutrality goals for 2020 and 2030 (Ministry of the Environment, 2021). Key measures include promoting renewable energy and accelerating the adoption of electric vehicles (EVs), plug-in hybrid vehicles (PHVs), and fuel cell vehicles (FCVs), aiming to achieve 100% penetration of these electrified vehicles in the new passenger car market by the year 2035 (Yamaguchi, 2022).

Despite these efforts, Japan lags behind other industrialized nations in EV adoption, with consumers exhibiting reluctance to purchase electric vehicles despite extensive marketing efforts. In contrast, countries like China, South Korea, and Vietnam are experiencing a surge in EV popularity, while others such as Thailand, Malaysia, and Indonesia are embracing EV production technologies to stimulate economic growth (Purtanto, 2023).

Given that Japan heavily relies on automobile manufacturing, which accounts for nearly one-fifth of its exports, the nation faces the prospect of economic stagnation should it fail to transition towards electric vehicle production (Electrek, 2022). This pilot study aims to investigate EV demand in Japan through a nationwide survey targeting individuals aged 20 to 70 who own cars. Alongside geographic and demographic data, the study will employ conjoint analysis to identify attributes prioritized by respondents in their prospective car purchases.

3 METHODS

3.1 Plan Cards

We conducted a full-profile-rating conjoint analysis to explore the factors influencing the purchase of private cars, drawing upon previous research on the demand for environmentally friendly vehicles. Initial factors were identified through previous literatures(Jung, et al.,2022; Khan,et al.,2020; Kowalska-Pyzalska,et.al., 2022; Kajiwara & Muromachi, 2023; Ito & Managi, 2015) and interviews with five randomly selected car owners nationwide. Ultimately, four factors were chosen for the empirical study: 1. the nationality of the manufacturer, 2. the cruising range of the vehicle, 3. the vehicle type, and 4. the price.Table 1 outlines the characteristics of the products examined in this study.

To assess consumer preferences, we created various product profiles, or "plan cards," based on different attribute levels. Respondents evaluated these profiles, resulting in a total of 36 potential combinations (3 × 2 × 3 × 2). To streamline the selection process and minimize bias, we employed Fisher's factorial design to reduce the combinations to 11 plan cards using IBM SPSS conjoint software (version 19). Respondents were then presented with these 11 plan cards and asked to imagine purchasing a new car, rating each card based on its characteristics. Ratings were provided on a five-point scale ranging from 'strongly considering purchasing' to 'not considering purchasing.'

Attribute	Level 1	Level 2	Level 3
Country	Germany	Japan	China
Car's range	500km	200km	-
Type	EV	PHV	Gasoline car
Price	3,000,000JPY	1,500,000JPY	-

Table 1: Levels and Atrributes

Equation (1) presents the consumer behavior model utilized in our analysis:

$$\text{Estimated consumer's utility} = \beta_0 + \beta_C \times \text{Country} + \beta_R \text{ Range} + \beta_T \times \text{Type} + \beta_P \text{ Price} \quad (1)$$

When selecting a car, consumers aim to maximize their utility by considering various features. In this model, utility serves as the dependent variable, representing the customer's utility function. It encompasses different attributes, with the utility of each attribute assumed to be quantifiable. Thus, the total utility is calculated as the sum of individual attribute utilities.

Equation (2) outlines the model for determining the average importance of each attribute:

$$\text{i attribute's importance} = R_i / (R_C + R_R + R_T + R_P) \times 100 \quad (2)$$

Here, importance i represents the average importance of attribute i, and Ri denotes the value range of the utility factors associated with attribute i. The subscripts C, R, T, and P correspond to the attributes of country, range, type of vehicle, and price, respectively. The calculation yields each attribute's relative influence, expressed as a percentage summing to 100%. This computation is conducted for each respondent, and the average importance across all respondents is derived.

3.2 Descriptive data

A nationwide consumer survey was conducted from March 8 to March 9, 2024, utilizing a web-based survey platform. The questionnaire encompassed several sections. Initially, respondents provided demographic information, including gender, age, household income, marital status, presence of children, and residential area. Subsequently, they were presented a list combining the attributes of cars. Table 2 summarises the statistical data.

Variable		N	%
Gender	Male	476	72.2
	Female	183	27.8
Age	Young adults (ages 20-39)	83	12.6
	Middle-aged (ages 40-59)	326	49.5
	Old age (60 above)	250	37.9
Household Income	Low income group (below 500 million JPY)	214	32.5
	Middle income group (500-below1000)	272	41.3
	High income group (1000 above)	101	15.3
	Pefer not to answer	72	10.9
Education	High School	168	25.5
	Jonior Colledge	123	18.7
	Undergraduate	324	49.2
	Graduate School	44	6.7
Marital status	Married	468	71.0
	Unmarried	191	29.0
Children Status	Present	419	63.6
	Absent	240	36.4
Region	Greater Tokyo Area	292	44.3
	Nothern	66	10.0
	Middle and Hokuriku	94	14.3
	Kinki	108	16.4
	Chugoku	56	8.5
	Kyushu and Okinawa	43	6.5

Table 2: Demographics

3.3 Empirical results

The model outcomes were computed utilizing IBM SPSS conjoint (version 26). Table 3 presents the empirical findings encompassing all respondents. Notably, the Pearson's R values were notably high (0.998), indicating a strong correlation coefficient between the values predicted by the model and the evaluation scores provided by the respondents. Higher values approaching 1 suggest a robust correlation coefficient. Additionally, Kendall's tau exhibited high values (0.778), affirming the reliability of the partial utility value calculations. Hence, the conjoint analysis model aligns well with the response tendencies of the respondents. Both Pearson's R and Kendall's tau are statistically significant (sig. < 0.000), indicating a well-fitting model.

Next, we examined the country's impact on consumer utility. The results revealed that Japan has the most positive effect on consumer utility values (+0.899), while Germany has the second highest effect (-0.127). China has the worst impact on consumer utility (-0.772). This attribute was the most important of all, with an average importance of 57.0%.

Then, we examined the effect of range on consumer utility. The high range (500km) positively impacts customer utility (+0.039). The low range (200km) has a negative effect (-0.039). This attribute had the 3rd degree of importance, with an average importance of 12.6%.

Regarding the type of car, PHV has a positive effect (-0.067), and the other two have a negative effect(EV: -0.018, Gasoline: -0.048). This attribute had the 2nd degree of importance, with an average importance of 18.7%.

Lastly, we examined the effect of price on consumer utility. When the price is reasonable (¥1,500,000), the effect on utility is positive (+0.051). High prices (¥3,000,000) have a negative impact (-0.051). The average importance of this factor is 11.4%, making it the least important factor.

Attribute	Estimation			
	Level	Utility	SD	Importance (%)
Country	Germany	-0.127	0.041	57.0
	Japan	0.899	0.041	
	China	-0.772	0.041	
Range	500km	0.039	0.031	12.6
	200km	-0.039	0.031	
Type	EV	-0.018	0.041	18.7
	PHV	0.067	0.041	
	Gasoline	-0.048	0.041	
Price	150	0.051	0.031	11.4
	300	-0.051	0.031	
Constants		2.218	0.033	
Pearson's R	0.998	Significance	0.000	
Kendall's tau	0.778	Significance	0.002	

Table 3: Empirical Results (All respondents)

3.4 Discussion

The results of our study shed light on what Japanese consumers prioritize when choosing eco-friendly vehicles and how these factors affect their decision-making process. Firstly, where the car is made, or its country of origin, emerged as the most influential factor. Japanese cars were preferred, followed by German ones, indicating that consumers pay close attention to where a car is manufactured. This factor held significant importance, with 57.0% of respondents considering it when making their choice. Secondly, the type of vehicle played a crucial role. Plug-in hybrid vehicles (PHVs) were favored, while electric vehicles (EVs) and gasoline-powered ones were less preferred. This suggests a preference for hybrid technology, possibly due to its perceived environmental benefits and fuel efficiency. Japanese automakers offer a wide range of hybrid models, which may contribute to consumers' confidence in this technology. Although less crucial, the range of the car also influenced consumer decisions. A longer range of 500 km had a positive effect, while a shorter range of 200 km had a negative impact. Lastly, while price remains a consideration,

it's not as significant as other factors like country of origin, car type, and range. This suggests that consumers prioritize these attributes over price when purchasing a car. These results can explain the current state of green vehicles in the Japanese market. For example, Nissan's Sakura was the top-selling EV in 2023, accounting for 40 percent of all sales with 37,140 units. The company's Leaf and Aria followed. China's BYD, on the other hand, sold 1,446 units, despite its vigorous marketing efforts and the introduction of low-cost, high-performance Evs (36Kr Japan, 2024).Our findings highlight the complexity of consumer preferences for car attributes and emphasize the importance for automakers to consider various factors when designing and marketing their vehicles.

4 CONCLUSION

Our research examines Japanese consumer preferences for eco-friendly vehicles, highlighting the significant influence of country of origin, vehicle type, cruising range, and price on car purchasing decisions. We find that Japanese consumers strongly favor domestically manufactured cars over foreign ones, with over 57.0% considering this factor crucial. Additionally, plug-in hybrid vehicles (PHVs) are preferred over electric vehicles (EVs) and gasoline-powered cars, reflecting a preference for hybrid technology. While price is a consideration, it is less important compared to country of origin, vehicle type, and cruising range. Overall, our findings underscore the complexity of consumer preferences and emphasize the importance for automakers to address these factors in vehicle design and marketing strategies to meet the demands of the Japanese market for eco-friendly vehicles. Future research endeavors should aim to explore the nuances in preferences among various segments of consumers, incorporating a comprehensive analysis of demographic variables alongside psychographic and behavioral variables. Additionally, further investigation could delve into the influence of cultural and societal factors on consumer preferences for eco-friendly vehicles.

5 ACKNOWLEDGEMENT

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Fourth Nature: Regenerating Cosmicity

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1 ABSTRACT

What characterizes the New Era? The New Era signifies a shift towards a heightened consciousness of interconnectedness and responsibilities, both within ourselves and with the external world. Our homes and cities are built in a way that discourages meaningful connections and lacks a sense of cosmic integration - they exist in isolation from the natural order. As humans, endowed with unique capabilities, we play a role in co-creating our reality. This underscores the importance of urban regeneration, which must occur in tandem with human evolution. Nature is ready to initiate the necessary regeneration urgently required. "Because we, as proud children of science and reason, have made ourselves orphans of ancestral knowledge and Nature wisdom" - as says Chopra. This is where the Fourth Nature concept emerges, offering a path forward: it ignites a new consciousness within us and becomes manifest in our living spaces The failures observed in current models stem from our failure to acknowledge ourselves and our creations as integral parts of Nature. While this separation may exist primarily in our minds, its effects are profound. To harness the full potential of our technological advancements, we must cultivate greater sensitivity, for the betterment of our own well-being and that of all humanity. It signifies a new paradigm. Our evolutionary journey depends on a significant leap in consciousness - embracing cosmicity, the state of being cosmic, integrated, and interconnected. The absence of Nature in our cities and lives is no longer tenable. The repercussions of this disconnect are palpable: natural calamities, widespread hunger, and pervasive poverty, despite the Earth's inherent abundance. Regeneration extends beyond brownfields; it is imperative across all urbanized areas where Nature has been neglected, disregarded, or excluded. The city of Porto Alegre, for example, has a former industrial area called Fourth District - a zone where Nature shows its power and presence amidst neglect. Towering trees calmly observe humanity's struggles under its shadow. Wild fruits and flowers thrive along walkways, while old buildings offer shelter to residents on cozy balconies and benches, in an interesting scale. Revitalizing this area may not be as daunting as it might seem. It involves more than mere preservation or devastation; it entails understanding the quality of the pre-existence as well as restoring the connection to local food production, implementing sustainable waste and rainwater management strategies, and employing intelligent, cost-effective building practices. This paper explores the idea that the success of the New Era hinges on such actions - where healthy living is not merely an option but the most accessible choice for all.

Based on Nature and enhanced by our true consciousness.

Keywords: comsmicity, new era, fourth nature, human evolution, urban regeneration

2 A NEW ERA OF CONSCIOUSNESS

In this article, attending the REAL CORP 2024 call for papers, some recent insights are brought under the topic: “Urban Regeneration and Revitalisation: Making Older Urban Quarters Fit for the Future” examining the prevailing trends and offering a new perspective into navigating the challenges, particularly in the brownfield area known as the Fourth District in Porto Alegre, South Brazil. A good starting point would be to acknowledge humanity's capacity to make decisions based on our experiences and thoughts, recognizing their mutual influence. Once we have the chance to experience good opportunities and situations, we might certainly opt for more situations that lead us to better experiences. Because we are conscious we can choose to be happy (CSIKSZENT, 1990). However, our daily lives often fail to provide optimal conditions, leading to unfavorable choices. The advent of the New Era hinges upon our collective and conscious pursuit of creating positive experiences available to everyone.

The Fourth Nature concept supports this objective by acknowledging that enhancing our relationship with Nature can improve our quality of life. It underscores the importance of integrating this relationship into our daily routines to promote positive transformations (PROCHNOW, 2020). Nature has the ability to bridge the contemporary divides that complicate the realm of life in our cities, demonstrating that this complexity is

neither inherent nor ideal. The joy of strolling beneath a canopy of trees on a sunny day can profoundly alter our perception of a neighborhood or street, as well as change the way we mentally start our day. This exemplifies how the Fourth Nature concept elevates the relationship between humans and Nature. It prompts us to recognize ourselves as part of Nature and to acknowledge our role in transforming it into our culture, into our cities.

Cicero, writing before Christ, brought up a concept known as Second Nature, wherein humans modified the natural environment to fulfill essential needs such as food and transportation. Later, during the Italian Renaissance, scholars like Jacopo Bonfadio explored the idea of a Third Nature - "una terza natura" - where humanity altered Nature for aesthetic pleasure. This involved the creation of elaborate gardens where technology and art converged to enhance enjoyment and appreciation of the natural world (HUNT, 1992). Therefore, the Fourth Nature concept, as developed in my thesis and research, presents the potential for a new level of interaction. It underscores the realization that, despite numerous catastrophes and calamities, we cannot afford to disregard Nature's power. It emphasizes that aligning ourselves with Nature's cycles and rhythms will lead to greater happiness and well-being, precisely because we are inherently connected to them.

We can understand that living in alignment with Nature means designing and planning our lives to coexist harmoniously with the natural world, learning to observe its characteristics and evolving alongside it. The consistent presence of Nature in our lives possesses the transformative power to awaken us from the sense of disconnection and hypnosis that pervades modern existence. When we reconnect with our surroundings and recognize our ability to shape our environment, we begin to realign with our true path. This mutual influence between humanity and Nature has the potential to revolutionize our approach to planning and ultimately reshape our reality.

Central to this shift in consciousness is the recognition that we are the builders of our own world, shaping it through our choices and actions. By tapping into Nature's wisdom and drawing upon ancestral knowledge, often rooted in natural principles, we can find solutions to the challenges we face. Urban regeneration belongs to the advent of the New Era, which hinges on our ability to reclaim these capacities, becoming conscious human beings once again. This explains why regeneration will only happen in a positive way when together with human evolution - my research scope of attention at this moment.

3 COSMICITY

Cosmicity represents a state of being interconnected with the cosmos, integrated and intertwined with the universe. This state is inherent to our existence, yet we find ourselves in a paradoxical reality where the natural flow of life is disrupted and the outcomes we experience fall short of satisfaction, highlighting these ruptures in our connection. The absence of a holistic understanding exacerbates this disconnection, hindering the natural flow of existence. Given that architecture and urbanism serve as the intermediary layer between us and the natural world, they wield the ability to either strengthen or weaken the crucial connection that eludes us. Our cities, constructed without due regard for Nature, overlook our inherent dependency on it, thereby contributing to the illness afflicting both us and the urban landscape itself.

Amerindian communities do not have a distinct term in their language to encapsulate the concept of Nature. Instead, they perceive reality as a seamless continuum, wherein humanity, animals, plants, and celestial bodies are intricately interconnected and share responsibilities in the continual creation and recreation of life (KRENAK, 2020). The notion of cosmicity explored in my research closely aligns with this perspective, emphasizing principles of unity, respect, and reverence for all forms of life. Without this vital connection to life's sources, our evolutionary trajectory may culminate in our own demise, as some scholars suggest has already occurred on our planet (TOMAS, 1972). I share a positive view, in which we are able to perceive the turning point that is getting clear in front of us.

The idea of cosmicity encompasses the idea of interconnectedness across various scales, in a fractal pattern. Positive outcomes achieved on a small scale have the potential to reverberate and manifest on larger scales. For instance, managing household waste responsibly, mirroring nature's efficient transformation processes where nothing is wasted or lacking. Reevaluating consumer habits, such as repurposing used items or supporting local producers by purchasing fresh produce from nearby markets, thus reducing the need for packaging and transportation. Adopting a fresh plant-based diet. All these actions hold transformative

potential, not just on an individual level but on a global scale. However, to actualize these changes, it's essential to reside in environments that foster and support such sustainable actions.

We can think of cities worldwide as intricate cellular structures composed of smaller units such as houses and buildings. These smaller units, in turn, consist of materials used in construction, analogous to the components of our bodies. The activities within our homes and cities, including the consumption and disposal of resources, collectively impact the planet. Similar to how our bodies require sunlight and clean air to thrive, healthy homes need access to natural elements. Just as our bodies derive energy from natural sources, the vitality of our homes depends on harnessing and processing energy from renewable sources.

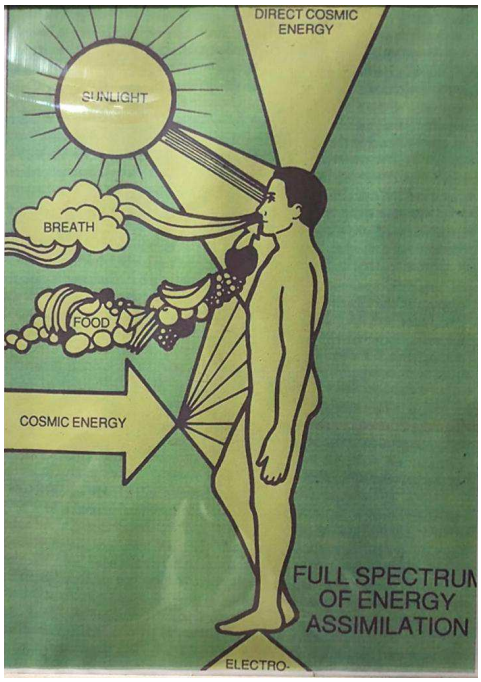

Fig. 1: Energy assimilation by the human body (public domain).

Indeed, it's truly remarkable to acknowledge the depth of our interconnectedness with the world around us and our reliance on it for our overall well-being (see Figure 1). The full spectrum of our bodies' energy assimilation derives energy from a diverse range of sources, encompassing not only food but also sunlight, cosmic energy, air, and electromagnetic energy from the ground. However, for those of us residing in urban environments, the opportunity to experience direct contact with the ground, even for a brief period each day, is often limited.

This raises a pivotal question and reflection, which lies at the heart of this paper: regeneration must take these fundamental basic well being issues into consideration. At the heart of the matter lies the need to design and redesign our cities with a clear understanding of what constitutes a healthy life. Recognizing our inherent connection to Nature shouldn't be complicated or intimidating - it should be evident. Integrating green spaces into buildings, ensuring ample access to sunlight, establishing communal composting areas and vegetable gardens - these are all embodiments of the Fourth Nature concept. It's widely recognized that Nature provides solutions to a diverse range of challenges, encompassing both physical and mental well-being, as well as addressing social needs.

As urban planners, we frequently discuss the concept of multipurpose urban spaces. However, there is often insufficient dialogue about Nature-based solutions and environments. Reintroducing Nature into our cities across all scales represents the turning point for successful regeneration efforts. Fourth Nature suggests that by revitalizing our cities, we can also revitalize humanity, and vice versa. Embracing a holistic approach to this process unveils the untapped potential for profound transformation. Significant changes can unfold within a relatively short time frame, guiding us back to our rightful place within the natural order. We are the fruit of an ancestral lineage deeply rooted in Nature. This ancestry, this biophilic being is with and within us, accompanying us wherever we are, whether in the forests or in the big city (GIMOVSKI, 2023). Cosmicity, much like Fourth Nature, resides within us - it simply awaits our acknowledgment to manifest externally.

“Study Nature, love nature, stay close to Nature, it will never fail you”. Frank lloyd Wright

Numerous studies and authors have explored the topic of longevity, yet the essence lies in healthy longevity. Undoubtedly, the world has undergone significant changes over the years, decades, and centuries—we're in a constant state of flux. However, it's crucial that we glean insights from these transformations and integrate them into our lives. True regeneration entails not just a focus on quantity but a commitment to quality. While the demands of a global population exceeding eight billion are undeniably significant, we possess the resources to navigate these challenges. What escapes us is consciousness over the utilization of renewable resources, which are vital elements we are not fully caring about.

Technology offers avenues to address and enhance our urban landscapes. However, Fourth Nature advocates for more than just technological solutions; it emphasizes the importance of reclaiming ancient knowledge and tapping into Nature's inherent wisdom. By reestablishing our connection with the natural world, we can restore a sense of quality to our lives in a much easier way.

So, what are the essential ingredients to live well?

Security and freedom are foundational human needs. Security encompasses the sense of safety within our homes, communities, workplaces, and urban landscapes. Likewise, freedom flourishes when individuals are empowered to make choices and have the necessary conditions to access a realm of possibilities. However, many of today's cities fall short in providing environments conducive to fulfilling these needs.

4 THE DESIRED FUTURE MAY HAVE ALREADY EXISTED

Cities everywhere around the world are undergoing transformations fueled by evolving human needs and perspectives. However, true change will only materialize when we collectively realize our interconnectedness with Nature. The aftermath of the pandemic has released a wave of pent-up desires and vocations. We all noticed how unhappy we were when we were forced to be locked in, disconnected from our passions and loved ones. Our existence does not flourish when we have no time to contemplate being here and now. We get sick when we feel disconnected.

Porto Alegre, located in southern Brazil, has long fascinated me for several reasons. Firstly, its reputation as a relatively green city stands out, with over a million trees cohabiting alongside a population of one million and three hundred thousand residents, almost equating to one tree per person. Additionally, my interest in architectural heritage is piqued by Porto Alegre's potential to blend old and new, revitalizing historic buildings to play an active role in contemporary urban life. This fusion of different eras within the same space forms the basis of my dissertation, titled Heterochrony in Architecture - The Project as Heritage Enabler (PROCHNOW, 2016), which explores the dynamic outcomes of such juxtapositions in urban environments. Porto Alegre is home to a former industrial area known as The Fourth District, which has a lot of character and historic significance. Despite its interesting characteristics, this area has remained largely dormant for decades. However, in recent times, it has garnered renewed interest and popularity. The image of the spatial environment, the mental representation of the character and structure of the geographic world – according to Kevin Lynch in his book What Time is this Place? - is like a support to which we attribute many meanings and a guide by which we can order our movements. This image has an immediate practical function in our lives, and an even deeper psychological function. Many parallel statements can be made about the environmental picture of time in our collective memory as well as in each one of us. Both have intimate connections to landscape aesthetics and more general implications for social structure and social change.” It is clear that we must think about an environmental image that is both spatial and temporal, just as we must design environments in which the distribution of qualities are considered in both time and space" (LYNCH, 1972). We could say the Fourth District has the biggest luxury of our time: space. Free space in an already urbanized area. Coupled with space, it has diverse architecture and a vibrant community. These important features present what is considered to be an ideal canvas for future cityscapes. What was clearly identified in the research as points that deserve attention, in the Fourth District as well as in many other areas of different cities, are Nature and infrastructure - exactly two ingredients that together are catalysts in the processes of urban regeneration. By embracing nature-based solutions and implementing blue-green infrastructure, we can unlock the district's full potential as a hub of creativity and sustainability. This intentional approach to design has the power to transform the Fourth District into a model for innovative and environmentally enriching urban spaces.

The Fourth District is positioned along the shores of Lake Guaíba but tragically severed from its natural connection. Over time, the area underwent significant waterproofing, leading to the loss of its wetlands. Moreover, the infrastructure has remained outdated, and vegetation has proliferated unchecked in certain areas. These conditions present a formidable challenge for the district's successful regeneration efforts.

Amidst these challenges, the Fourth District boasts intriguing examples of architectural remnants dating back to the early twentieth century and subsequent decades. These include industrial structures, workers' patio-houses, and smaller buildings, each representing different scales of urban living. However, I wish to emphasize the significance of residential buildings in this paper. They serve as a testament to a bygone era when daily life epitomized community, connectivity, and harmony with nature. Residents lived within walking distance of their workplaces, fostering strong connections with their surroundings and promoting social interaction and a sense of community. These residential buildings in the Fourth District gather some of these qualities, in different combinations. This is what we are looking for, today.

Some of these buildings still stand resilient (see fig. 2), as a piece of resistance, despite facing challenges from social, economic, and environmental pressures, as well as the influence of the starting real estate production. When prompted to "keep planning for the real world," especially in revitalizing old areas to meet contemporary needs, it seems prudent to carefully consider what these needs entail. It's possible that the solution for them has already existed, and we merely need to adapt them to our current circumstances. In truth, genuine progress reminds us that our fundamental human needs remain relatively unchanged over time. However, we often overlook them, distracted by the multitude of tasks and information that bombard us daily.

Fig. 2: Example of a street atmosphere in the Fourth District today - the desired future may have already existed. By the author.

5 CONCLUSION

The concept of evolution proposes that new forms arise from those already present in the world.

It's fascinating to observe that elements reliant on Nature are undergoing self-regeneration in the Fourth District, even after years of stagnation. Features influenced by Nature's rhythms and cycles have adapted on their own, without human intervention. Now, the priority should be to facilitate and support this process towards desired outcomes: nature-based solutions for revitalizing urban life.

The pressing need for housing can start by the regeneration of the existing constructions - renewing the ones that are still there, updating its liveable conditions, but most of all, understanding and valuing its qualities and using them as inspiration for building new ones, that mirror their standards. They seem to show more clearly what should define a project, made at a time when the financial result was not exclusively what determined the rules.

Towards which objective are we going to regenerate the city? In this context, Fourth Nature endeavors to forge a new paradigm that blends past achievements with the evolving concept of interconnectedness and harmony. It is entirely plausible to develop our cities and rejuvenate established communities guided by these principles. The initial step entails recognizing the merits of the past: discerning successful strategies, understanding their functionality, and extracting valuable insights from seemingly static scenarios for our imminent future (see fig. 3, 4, 5 and 6). After all, the extreme speed in which things change does not seem to be a good leitmotif.

To return to the right path we first must reassess our values and aspirations, and cultivate a deeper understanding of our objectives. What fundamental experiences truly define our humanity, and how can our urban environments facilitate them? It begins for example with integrating nature into our surroundings - balconies adorned with greenery, providing a tangible connection to the changing seasons. Neighborhoods where local markets bring fresh produce from farm to table. Active ground floors where artisans and small entrepreneurs can showcase their handcrafted goods and services, fostering community engagement, face-to-face interaction and above all, self realization. Living close to public green places that provide tranquility for casual gatherings and local cultural events.

Ultimately, by designing a world that prioritizes human experience in a harmonious relationship with Nature and consequently with the whole cosmos, we can pave the way towards the possibility of having a new story to tell (GLEISER, 2023). The higher a civilization ascends, it is paramount to firstly seek internal realization in order to stabilize society and then subserve the solution of its material problems.

Coexisting in harmony with Nature is key.

Fig. 3,4 and 5: Some dynamics existing in the Fourth District nowadays – this is REAL. By the author.

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How do They Ride? Analysis of Cycling Biomechanics ("MODELO-Rad" Project)

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1 ABSTRACT

For the planning and design of appropriate cycling facilities, aspects such as capacity, continuity, and objective safety are often subjects of research, but an understanding from the cyclist´s perspective, including physical and biomechanical characteristics, remains superficial. Findings related to cyclist behaviour have not yet been systematically applied and there is limited information on the relationship between cycling behaviour and characteristics of transport infrastructure.

The "MODELO-Rad" project aims to understand and model cycling from the perspective of cyclists. Desired speed, riding strategy, and braking distance, among others, are important for understanding bike rides and provide insight on the behavioural characteristics of cyclists from a biomechanical perspective. This research suggests that a bike ride in an urban area can be divided into distinctive behavioural phases, characterized by degrees of power, speed, and cadence. To capture patterns of behaviour among cyclists, this study had participants ride along different routes on "SensorBikes," which are equipped with sensor technology, to collect over 300 km of observations.

The empirical analysis finds that cycling can be described as behavioural phases between stops (mostly between intersections): an acceleration phase, characterized by high power peaks; a route phase, which is subdivided into stages according to the route conditions (constant travel, deceleration and intermediate acceleration, uphill and downhill rolling); and an approach phase to the stopping point, usually at traffic lights or road junctions. Within these phases, results vary substantially between different cycling facilities and across different groups of cyclists. This description of cycling as a mechanical process can serve as a basis for the development of a micromodelling approach to cycling behaviour and can consequently be used to improve the planning of cycling networks and bike infrastructure.

Keywords: infrastructure, planning, biomechanic, behaviour, cycling

2 COLLECTION DATA DESIGN

To identify the most relevant aspects of a bicycle ride, different cycling scenarios were observed. The design of the data collection was conceived in such a way that all possible combinations of influencing factors, such as speed variations due to different forms of infrastructure, interactions with other road users, the pedalling power of cyclists before and after traffic-light intersections, and the cadence on uphill sections, were included in a route.

The data collection involved a series of test rides in which the results were progressively evaluated and discussed. The initial test rides presented in this study involve the collection of data for the variables previously mentioned. In the first test, rides on two different routes and eight cyclists totalling over 170 km of observations were carried out. Aspects such as the type of cyclist, the type of bicycle or the representativeness of a specific population were not addressed in this first approach. Based on initial results, a more extensive data collection study including more cyclists and different routes is currently under development.

2.1 Measurement equipment: The "SensorBike"

The data collection required equipment suitable for measuring individual cyclist behaviour. Although research into cycling mobility is relatively new, there are technological developments oriented towards professional sport, which have been integrated into the research of cycling as a mode of transport. Such is the case of different sensors and technologies with a wide variety of configurations that allow the collection of data that were previously uncommon or impossible to measure (Temmen, 2022). The Karlsruhe University of Applied Sciences has progressively realized this idea with the use of different measurement equipment in its bicycle laboratory. The so-called "SensorBike" is a bike and measurement tool, equipped with sensors that enable a large amount of data to be collected simultaneously and then synchronized for analysis (Eckart

and Merk, 2021). In this research, the SensorBike collected sensor data for an analysis of the speed, power, and cadence with which the cyclists rode. These three biomechanical variables evaluated from the individual use of a bicycle provide a detailed source of data for evaluating possible variations of speed, power and cadence according to different types of cycling scenarios along predefined routes.

The SensorBike facilitates research into cycling from the perspective of cyclists. For the planned test, two cameras and a bike computer were used in conjunction with the SensorBike. The cameras were used to record the cyclist's field of vision and the use of the brakes. GPS data, speed and route progression, among others, were obtained from the recordings with the bike computer. Sensors built into the test bike were attached to the bike computer, which measured and stored cadence and power.

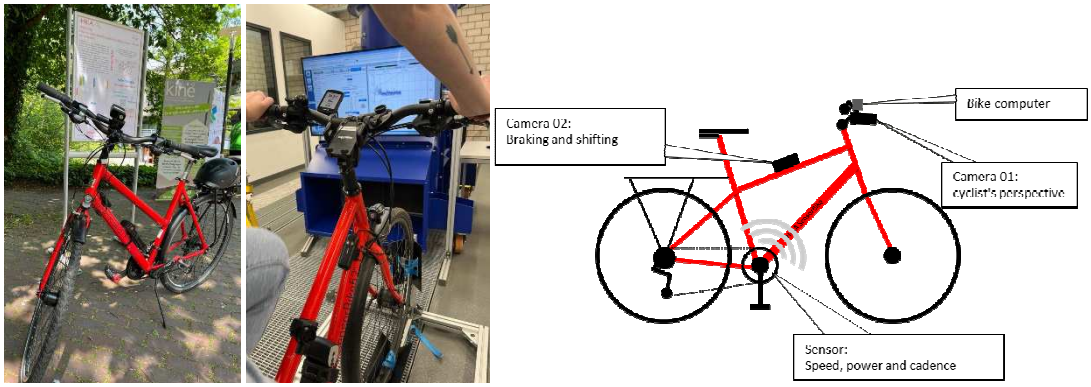

Fig. 1: The “SensorBike”.

2.2 Routes and data collection procedures

Different routes were analysed to assess the relationship between cycling infrastructure attributes and cycling. The following aspects were taken into account when creating the routes:

- Frequent interactions in mixed traffic
- Presence of traffic lights
- Sections with priority for cyclists and pedestrians
- Sections with high traffic volumes and parked vehicles
- Sections with ascents and descents of varying gradients
- Sections with interruptions (bus stops, road works, junctions, etc.)
- Sections with no interactions (free-flow travel: desired speed, desired power.)

This resulted in two routes in Karlsruhe, which were divided into sections of equivalent length and similar characteristics (maximally-homogeneous sections). The selected routes totalled a length of approx. 15 km, along which different forms of cycling infrastructure or mixed traffic conditions exist. As shown in the figure below, some of the sections have a high presence of pedestrians and interactions with motorized vehicles. Other sections have more free space, long longitudinal sections, or specific traffic rules.

Fig. 2: Examples of sections on selected routes

The data collection procedure involved three general steps:

- The SensorBike was calibrated and its sensors linked to the bike computer. The test subject received the bike with calibrated sensors, could adjust the height and gears of the bike for optimal use and received instruction for the route.
- The participants performed the test individually and rode the routes sequentially. Participants were instructed to ride as they normally do, and to follow the route marked by the GPS device.
- At the end of each ride, the ride was stored in the bike computer and its data verified. The video from cameras were extracted, differentiating the observation perspectives for their subsequent analysis.

Data quality was ensured by filtering sensor data and the associated video information. To analyse the information, the generated coordinate points (saved every 2 seconds) were displayed in order to link them with the attributes of the routes.

3 SPEED, POWER, AND CADENCE OF A BIKE RIDE

Speed is one of the most commonly used variables for the analysis of bike rides. A speed profile provides an important reference for trip dynamics along a given route or segment.The power exerted by a cyclist is another fundamental variable in the analysis of a cyclist's dynamics and efficiency. Examining cycling power or speed in isolation does not allow a comprehensive analysis of bike rides, but relating them to each other provides important indicators of cycling efficiency in terms of ride performance (Eckart et.al., 2022). Relating speed and cyclist power allows the identification, characterization, and analysis of different cycling situations. One of great importance is the shifting strategy, in which cadence plays an important role as connecting element between desired speed or desired power. Two schematic representations of the observed relationships between the study variables are used in the analysis.

3.1 Aggregate Observations of speed, power, and cadence of all test rides

The power and speed of all test rides can be presented over the ride distance. Figure 3 (left) illustrates changes in speed for participants along 5 Km on the route 01 of the test. It illustrates that a bike ride in an urban setting is characterized by a series of sections delineated by stops at (largely) intersections. Alternatively, visualising power/speed (P/S) ratio data the route (Figure 3, right) results in a dense concentration of points, which provides a first insight into the desired speed and power of each cyclist. The P/S point cloud shows certain distributions of the values when cyclists pedal at a given speed. A first example extracted from the collected data is visualized in the following figures, which show the speed profile of different rides of the same route, as well as the P/S point clouds for these profiles. Although the point cloud does not clearly present specific patterns to be analysed, it allows to observe in a general way, areas of concentration for some of the cycling rides (same colours as in profil). The points allow a range of speeds to be identified between about 10 and 30 km/h, with 20 km/h being the approximate mean value of the point cloud.

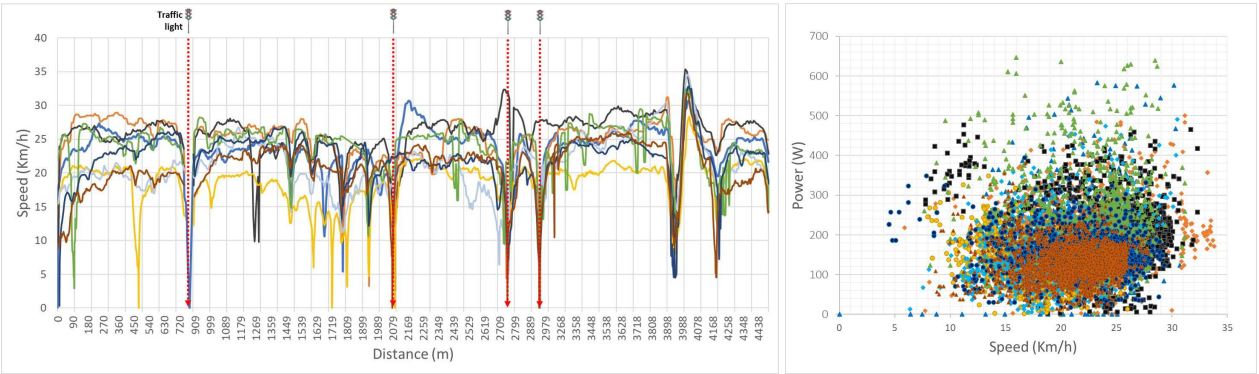

Fig. 3: Speed profil (left) and power-speed point cloud (right) of route 01 by participant

3.2 Aggregate Observations of speed, power, and cadence of a single section

In order to interpret the relationship between speed and power more clearly, it is helpful to focus on the P/S data for a single section of the bike ride between two stops instead of the whole route, for all cyclists. Figure 4 shows interpretations of P/S dynamics. On the left is an illustration of speed, power, and cadence profiles

over a distance of approx. 770 m between two intersections. The right illustration is a P/S point cloud for the same section.

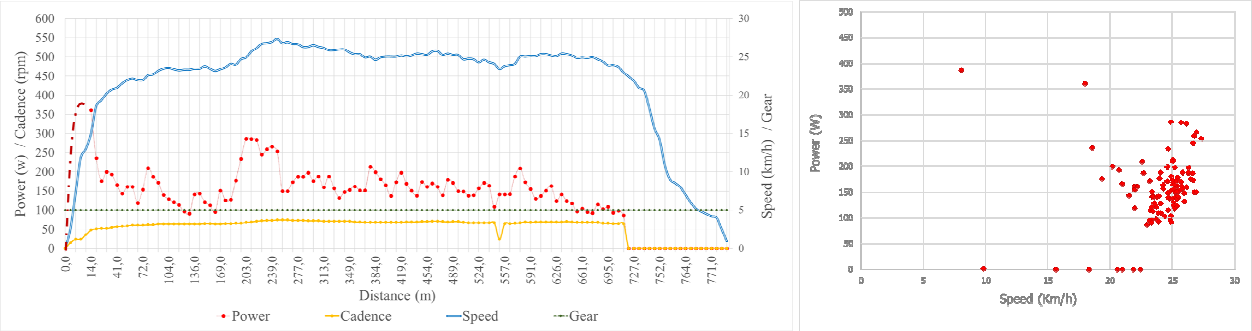

Fig. 4: Speed, power, and cadence profiles (left). Point cloud for same section (right). Example section of route 01

A visual inspection of the profiles and the P/S distribution identifies the following elements of ride dynamics:

- The point cloud shows isolated points in the high power, lower speed areas and on the 0 Watts line at different speeds. These points are associated with the beginning and end of the section, where acceleration and deceleration occur.
- The concentration of points observed as a cloud is related to the intermediate section of the route. The changes observed in the speed profile are associated with variations in power and very slight changes in cadence (when the same bike gear is maintained). This example relates to some research data on the power generated by cyclists, such as that reported by Knoflacher (1995) who highlights values of between 65 and 160 watts or Wilson (2020), who indicates an average value of 150 watts.
- By comparing the point cloud for numerous bike rides with the point cloud for one section of a single bike ride only, it can be observed that the point concentration for a specific ride may significantly vary with respect to others.

3.3 Different phases of a bike ride and the “riding cycle”

A single section of the bike ride can be characterized in detail, in terms of a series of phases. Four phases can be observed in the point clouds. The first phase corresponds to the beginning of the section where the cyclist accelerates until reaching a desired speed. The second phase is related to the progression of the section, where there are variations in speed, power, and cadence as a result of the cyclist's desire or adjustments according to route characteristics. The third phase is related to the cyclist's deceleration after recognition of the stopping point and the fourth phase, once the stop has been reached. The following figure represents the observed progression of phases.

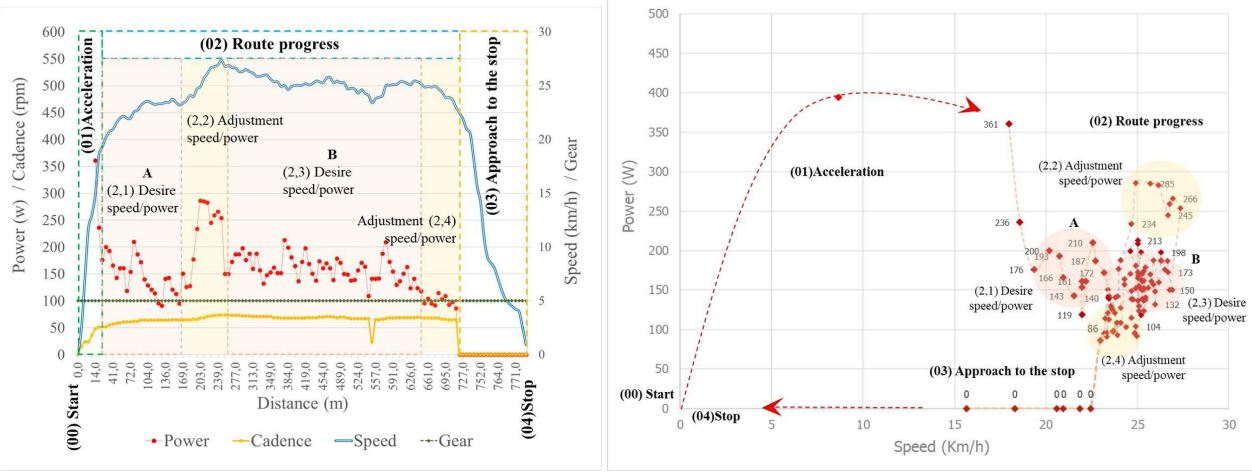

Fig. 5: Analysis of the speed and power adjustment for an evaluation section (example section of route 01)

The different sections of the bike ride share a similar pattern, in which three characteristics are observed: high-power peaks are reached at the beginning of the ride, the concentration of points is observed in sections

where there are no interactions or obstacles, and the adjustment of speed or power leads to new concentration points. As soon as the rider stops, this pattern resumes, leading to the observation of different trends depending on the riding scenario.

Based on this oberservation, a bike ride in an urban setting can be described using four phases, including the stops as a waiting phase, which form a “riding cycle” from junction to junction. The phases of the “riding cycle” reflect the desired speed, power, and cadence, allowing the mapping of the ride to identify clear boundaries between phases and riding cycles. In all phases, the shifting strategy plays a role in adjusting cadence and power output.

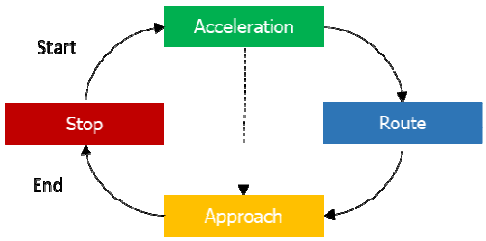

Fig. 6: The riding cycle of an urban bike ride and its phases

Taking into account that the distance between two stop points can be short, it is possible that the acceleration phase leads directly to the approach phase.

3.4 Subphases of the route phase

Interactions, interference, and sections with positive or negative slopes are crucial in the description of the riding cycle, especially in the route phase, where a detailed evaluation of these situations can identificy further subphases. Compared to the acceleration and approach phases, the route phase allows an extended analysis of the different triggers for the modification of cycling parameters. As presented in the following figures, an example taken from the collected data identifies the four general phases alongside the subdivision of the route phase. The speed profile of the general phases presents two riding cycles around signalized intersections, where the first does not have a route phase, considering the short distance. The subdivided speed profile for the route phase presents some of the triggers for speed changes and thus for the generation of subphases. Intermediate acceleration, constant ride, increasing resistance due to positive slope, decreasing resistance due to negative slope, and deceleration are the five sub-phases observed within the route phase.

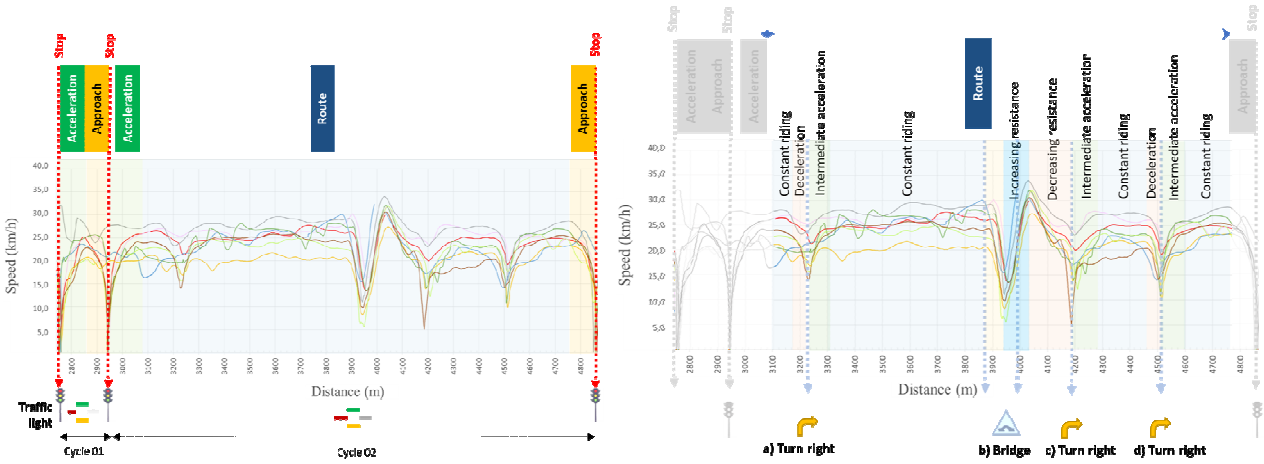

Fig. 7: Speed profile according to phases: General phases and subphases within the route phase (example route 01)

Speed reductions for turns or junctions, stops at signalized intersections, and interference caused by other road users such as pedestrians or motor vehicles are some of the main triggers observed in the test. Before, during, and after each of these triggers, the defined phases can be identified and to this extent, they can be analysed.

4 DESCRIPTION OF RIDE PHASES

In the following paragraphs, the different phases of a bike ride are presented in detail.

4.1 Acceleration phase

The first phase of the riding cycle represents the change of speed of the bike ride from the first movement of the cyclist until the desired speed is reached or until the acceleration is interrupted. Since this situation occurs after every stop, only acceleration phases associated with signalized intersections were analysed. Other stops due to other triggers were not taken into account. If the points collected for all acceleration phases are plotted as a function of the developed speed and the required distance, it can be seen that the data follow parametric functions and that the distances required to reach a desired speed cover an approximate range between 0 m and 130 m. As illustrated in Figure 8 (left), both a linear and a polynomial function are represented and calculated with a high R^2 value. The speed increases rapidly at the beginning and becomes slower the closer to the desired speed. On the other hand, as shown in the figure 8 (right) relating power and speed, different acceleration phases from five cases are characterized by high peak power and a concentration of points defined by the desired speed and power achieved.

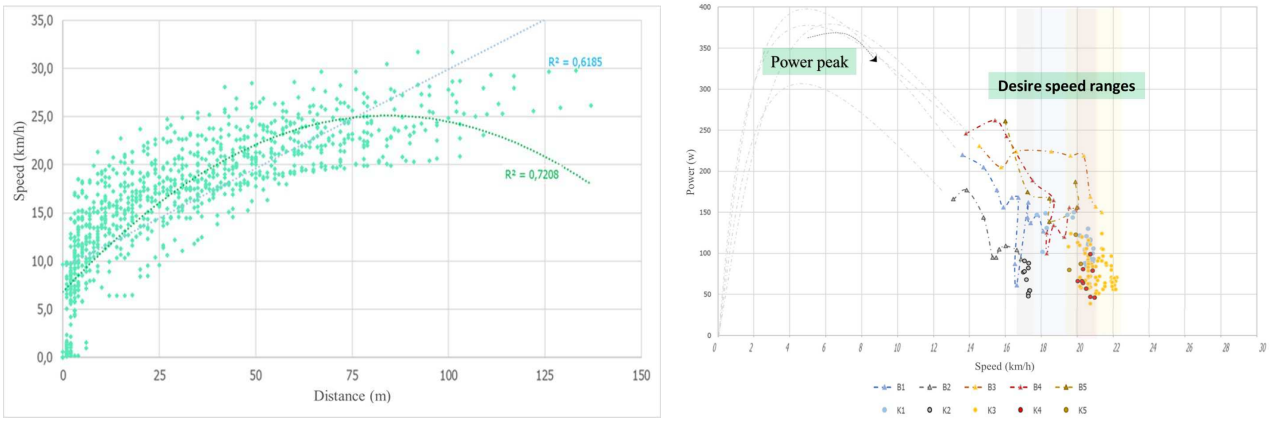

Fig. 8: Speed profile for the acceleration phase recollected from two routes (left) and example of four acceleration cases for the speed-power ratio (right)

In the following stages of this study, calibration improvements will be made with respect to the measurement of the power values for the acceleration phase. This is necessary because several cases were observed where the acceleration curve in its initial phase had no data. This limitation in the measurement with the SensorBike will be overcome by the use of additional calibration instruments.

An additional aspect of analysis regarding the dynamics of the three biomechanical variables (speed, power, and cadence) during the acceleration phase is the use of the bicycle's gears. Shifting patterns are different between riders. For the figure 9 (left) related to the profiles of speed, power, and cadence for a small sector, two moments of gear shifts can be observed. In the first (A), the cyclist shifts up and adjusts their cadence, which reaches a high number due to the previous acceleration. In the second (B), the cyclist shifts up again, decreasing the cadence and increasing the power, in order to continue raising their speed.

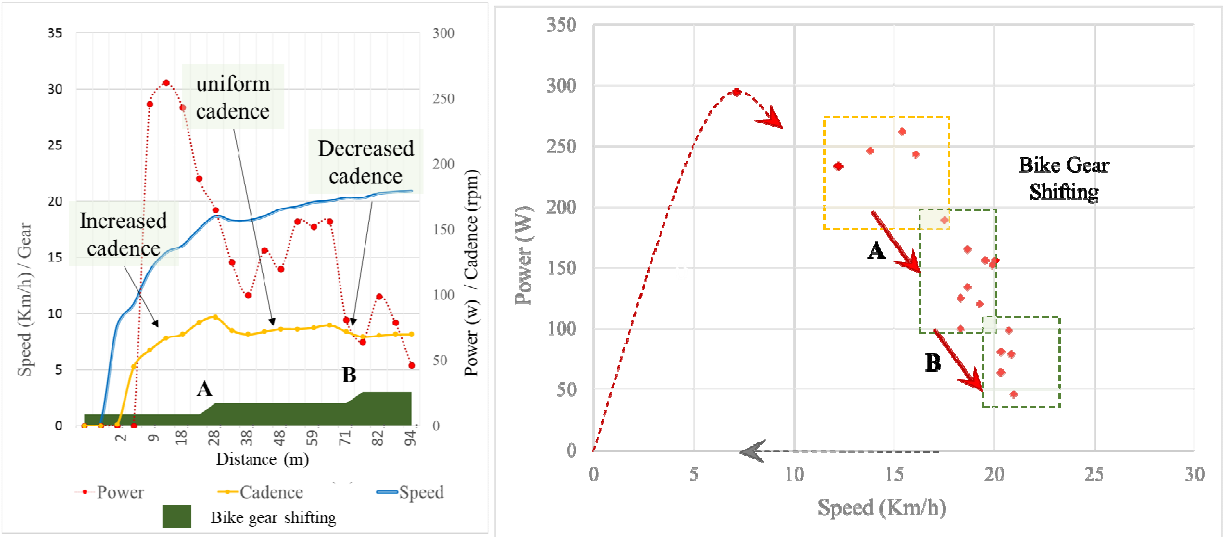

Fig. 9: Effect of bicycle shifting on cadence and power output for an evaluated section

Considering this example, it is possible to identify a couple of common characteristics around cycling dynamics and the power-speed relation:

The speed adaptations from shifting define specific areas in the representation of the power-speed relationship. These point concentrations are much more distant from each other when shifting is performed. Without shifts, as presented in the previous example, the displacement of the spot areas is mostly progressive.

The cyclist generally seeks to overcome interactions or interference as much as possible with a pre-defined power and speed. To achieve this, an optimum cadence is usually reached, which for normal cyclists is between 50 and 60 rpm (Gressman, 2022). This trend can be seen in the example presented as the final result of the two bike-shifting scenarios.

The shifting strategy is recognizable and allows certain riding situations to be described on the basis of external conditions. The most important example took place under increasing resistance. Empirical observations show differences between participants in terms of the use of gears, so this can be a starting point for future classifications of rider types, considering their relevance in the power-speed relationship.

4.2 Route phase

4.2.1 Constant riding

During the route phase, there are sections in which the cyclists maintain a constant ratio between speed, power, and cadence. The main reason for this is the absence of interactions or interference, resulting in an almost linear movement. The constant ride therefore corresponds to the best riding scenario for cyclists in terms of energy consumption and the ability to regulate it. On constant speed sections, the desired speed and power are achieved, but there may be several desired intervals. As presented in the following figures, the speed profile obtained for one of the rides relates specific sections of constant speed. These are represented in the power-speed graph, with which it is possible to observe a very specific concentration and range of points.

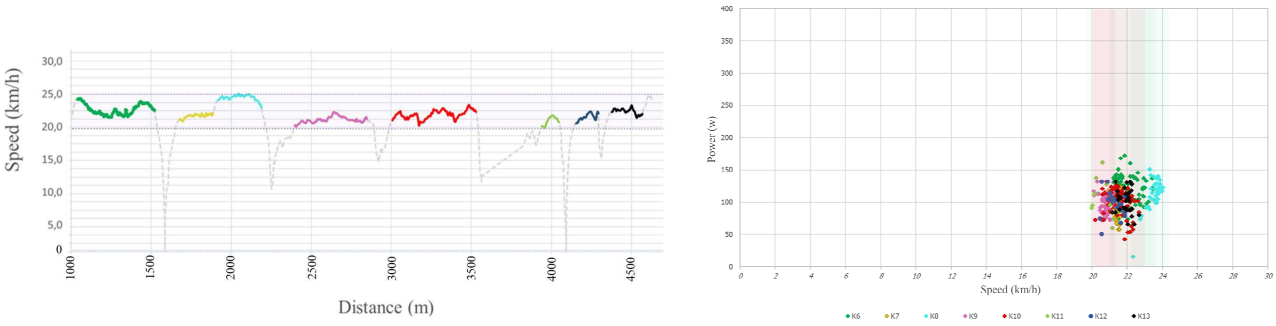

Fig. 10: Speed profile of a bicycle ride section and power-speed ratio

4.2.2 Intermediate acceleration and deceleration

Intermediate acceleration often occurs after deceleration due to braking. In this case, cyclists are forced to reduce speed as a result of interactions or interferences. Once the speed is reduced, the power increases in order to increase the speed again. The cadence depends on the shifting strategy, becoming faster or slower. In addition, a constant cadence of zero can also lead to deceleration, and this often occurs when cyclists ride with caution, such as in front of a traffic junction or in a pedestrian zone.

A second case arises as a result of the cyclist's desire to reach a higher speed. The long sections covered in the test (more than 200 meters) were often ridden at two speed intervals. This means that after a certain distance and a constant speed, cyclists increase their power in order to ride faster. This desire for higher speed is possible over distances without interactions or interference, or due to the desire to overtake other road users (usually other cyclists).

The deceleration observed in the collection data is linked to the braking or speed reductions where the power and cadence values are zero. A video analysis was carried out to describe the events. The observed braking was mainly identified in six situations:

- Before signalized intersections

- Before left or right turns
- At junctions with the 'right before left' rule.
- During interactions in pedestrian areas
- During interactions with other modes of transport, especially motor vehicles
- When adjusting speed after descending on sections with negative gradients

The deceleration caused by braking shows, for example along two of the evaluated routes, a speed reduction of up to 3 km/h in 58% of cases, and more than 5 km/h in 14% of the cases. The average braking distance for these routes corresponds to 17.3 metres. The deceleration caused by the absence of cadence is reflected in very short periods of time, mainly in situations where cyclists must decide whether to brake or return to pedalling. The use of the brakes and the effect of rolling by the inertia is the most frequent strategy to achieve a reduction in speed.

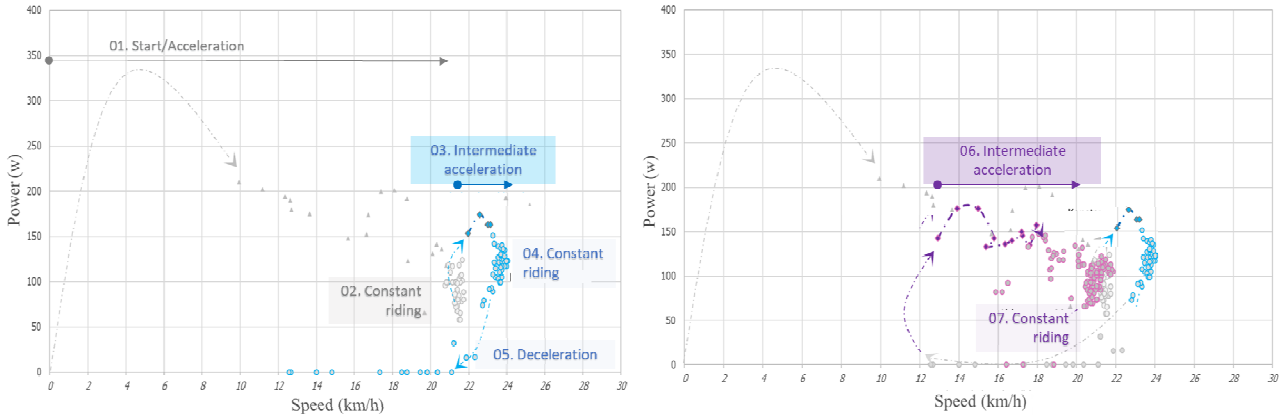

Fig. 11: Speed profile for the acceleration phases and example for the speed-power ratio

Increasing and Decreasing Resistance

Increasing resistance can be recognized on the basis of strenuous performance situations. Air resistance and climbing resistance are the most important and most frequent factors. The sections in the test performed with increasing resistance show acceptance of a higher power output (with limited lower cadence) for limited periods of time, which can reach the cyclist’s power limit, given the shifting strategy. Consequently, increased resistance due to gradients can very quickly become decisive for riding behaviour.

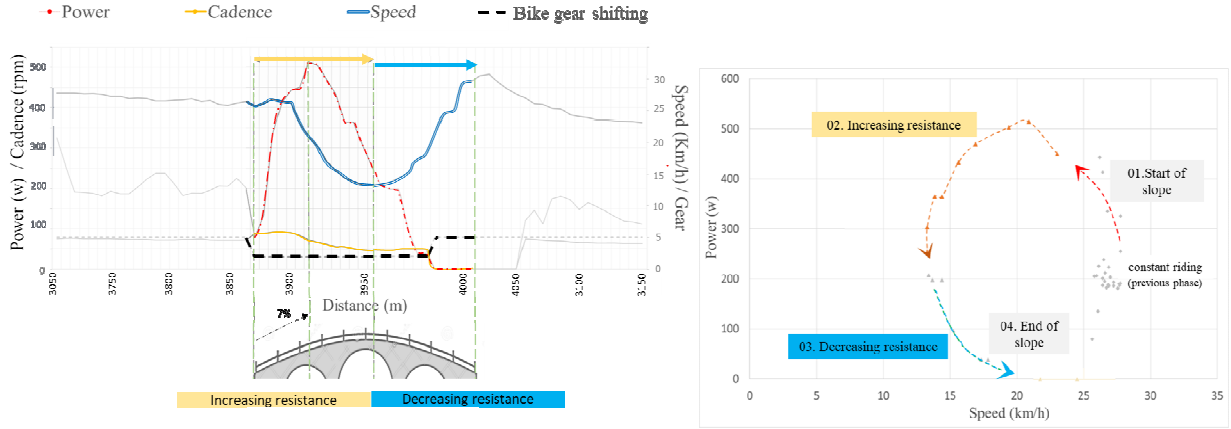

Fig. 12: Speed profile of a bicycle ride section with increasing and decreasing resistance and speed-power ratio

The power/speed values resulting from this situation show a different trend in the point cloud compared to all phases of the riding cycle. The first part of the P/S diagram shows a counterclockwise circle. An inverted "U" is shown with respect to the start of the slope and its highest point. Consequently, the speed increases and the power decreases due to the absence of cadence. In line with the results for increasing resistance, another situation can be described using a downward gradient. When the peak of the uphill section is passed, the power is considerably reduced and a high speed is reached. It is unclear whether the desired maximum

speed is recognizable in these results. It should be noted that all participants apply a speed adjustment, so the limit reached could correspond to a rider's feeling of subjective safety.

The resistance situations are illustrated below using an example one of the bridge sections along one of the evaluation routes.

4.3 Approach phase

At the end of the riding cycle, the last few meters before a stop are ridden under specific dynamics. Before cyclists enter the stop phase at a traffic light intersection, the final section is strongly characterized by cadence and braking. Cyclists recognize the red phase from a certain angle and distance. Subsequently, they react by reducing their speed through the braking function and stop pedalling. As a result, the speed adjustment results in an approach distance which can be influenced by different environmental conditions, such as type of infrastructure, traffic flow, weather conditions, or visibility of the traffic light.

Three situations were often observed in this phase: (i) The deceleration starts from a certain distance or time before the stop, so the main action is to stop pedalling, (ii) Cyclists pedal much more lightly or stop pedalling altogether, and (iii) subsequent, active braking occurs.

The speed values of the first 75 m (in the figure below between -100 m and -25 m) show a decreasing trend, so that the deceleration is clearly recognizable. Thereafter, the values are represented by a mostly decreasing trend, which means that the braking causes a rapid reduction in speed. The data collected in this phase for two routes are ilustraded in the figure below.

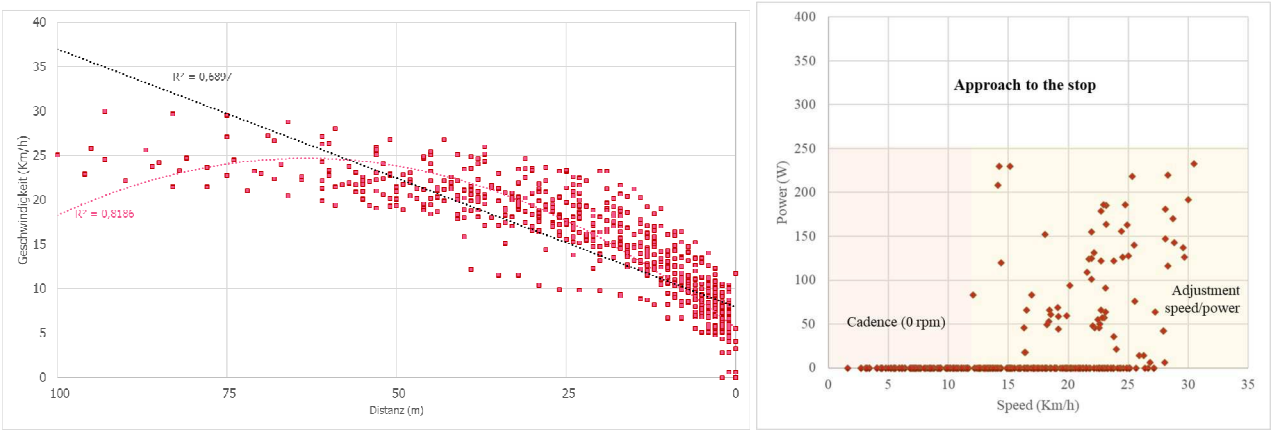

Fig. 13: Speed profile for the deceleration phase (Recollected data from two routes).

5 CONCLUSION

Cycling within an urban setting can be described in short sections between stops. The riding cycle concept leads to systematic analyses depending on the route. In this sense, a route can represent several riding cycles and can be divided into characteristic phases. Such phases are suitable for describing power, speed, cadence, braking, and the shifting strategy.

It is possible that there is a preference for one variable over another when it comes to bicycle riding (for example, speed as the main desire). In a riding cycle, several desired speeds can occur; however, it was not directly identified in the tests whether the desired power is the primary variable of desire or the speed itself. A possible way to identify the desired power is through the examination of shifting strategies. The power peaks avoided in the acceleration phase or in the route phase provide information regarding the desired power intervals.

Consideration for the speed, power, and cadence of everyday cyclists makes it possible to derive information for the planning and evaluation of cycling infrastructure. Efficient infrastructure has a low number of interactions between cyclists and other road users. In this case, cyclists need less power to reach a certain average speed than on sections where there are many interactions. This is due to the fact that braking processes and power peaks in the subsequent acceleration processes are eliminated due to the traffic situation. Furthermore, it is not necessary to reduce speed out of consideration for other road users. The test rides with the SensorBikes provide a survey methodology that allows the power requirements and speed of

cyclists to be measured in a comparable manner. This analysis can support cycle traffic planning and cycling promotion in identifying optimal route variants for cycle routes as well as inefficient network sections.

However, with the survey methodology of SensorBikes, parameters for the efficiency of cycling infrastructure can only be collected in existing situations. In order to take this into account in the planning of future infrastructure, tools for the microsimulation of cycling are required that can map the speed and power requirements of cyclists depending on the characteristics of the forms of cycling guidance, even for cycling infrastructure that does not yet exist. Hence, a micro-simulation for cycling should be developed, based on the physical modeling of bicycle journeys and biomechanical patterns from this study. The power and speed ranges that can be extracted from different situations are key for the development of modelling according to the biomechanical behaviour of cyclists. The patterns obtained in different cases suggest that it is possible to systematize the data obtained for cases related to cycling infrastructure, interference, or external conditions, among others.

The simulation tool is aimed at local authorities, engineering firms, and all stakeholders involved in cycling planning and promotion. It can support cycle traffic planning and promotion in the following tasks:

- Decision support for cycling route/infrastructure variants under consideration (identification of the variant to minimize travel time, power requirements, etc.);
- Identifying optimization requirements for existing and planned cycle routes/infrastructure with regard to time losses, performance, and safety;
- Area-wide evaluation of cycling infrastructure and identification of sections with potential for improvement (high performance requirements, high travel time losses, etc.);
- Estimation of cycling travel times for travel time comparisons with other modes of transport;
- Determining the effects of closing gaps and expansion measures in the cycling network on travel times and performance requirements as a basis for cost-benefit analyses.

Through simulation, the perspective of cyclists can represent a measure of quality and thereby effectiveness in the planning and evaluation of cycling infrastructure. The tool can be used for existing or future infrastructure. The planning processes can be standardized on the basis of the uniform cycling impact parameters provided by the micro-simulation

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Human Behaviour in Africa: a Real Challenge Factor towards Building Smart Cities

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1 ABSTRACT

Traditional behaviours and lack of education are two main elements that lead to resistance for change. However the new approaches of development, especially human centred design helps to break the ice and allow individuals and groups to lead the change by themselves. Humans in general and Africans in particular usually resist change. The old generation is not prepared to adapt and support the change. Using technologies in public services is a burden for them. The resistance for change from all community stakeholders including residents, local authorities and local business can slow down the process and delay the adoption of technology integration urban planification. However the inclusion of all stakeholders in early stages during the policy making process allows the success for change. Therefore, the success of building Smart cities in Africa and Morocco in particular needs to start from civil society integration in the decision making process. The idea needs to come from the people and the city council needs to play the role of the facilitator. Another factor is privacy and identity. Smart cities are defined by locals with limited or no education background as a tool for disconnection from the original culture. In the meantime, the privacy concern relates to collecting personal data of the citizens. Therefore, the city councils need to include this important element in their strategic action plans. Building trust and familiarising citizens with new technologies planned to be integrated in the citizen's daily life is a must. If there is lack of trust on how the personal data is protected during and after the implementation of smart cities' projects, it can lead to total rejection of citizens. Africa continents lack awareness and clear understanding of smart cities. The example of Agadir smart city in Morocco has exposed all mentioned challenges and obstacles. Despite significant investment put by the government and the local council to rebuild Agadir city with integrating technologies to enhance public service and create an environmentally smart city in Morocco. However, the cultural and social factors including societal norms can play a huge role in delaying the implementation of Agadir smart city. This factor will influence the interaction of citizens with integrated technologies in their daily lives.The municipality of Agadir action plan of 2022 to 2027 can be an example of citizens integration in the process of building and implementing smart city initiative through organising consultative meetings with all community stakeholders to have a say about the action plan.

Keywords: cultural and social factors, resistance for change, strategic planning, smart cities, human behaviour

2 THE AGADIR CITY COUNCIL AIMS TO BUILD A SMART CITY THROUGH A MINIMUM INCLUSION OF CIVIL SOCIETY AND ALL STAKEHOLDERS

The traditional approach adopted by public institutions in managing public affairs which build on working for citizens instead of working with citizens through linear decision-making lead to failure of development projects. This approach does not prioritise the inclusion of the citizens' needs in all project development phases. This fact leads to the appearance of new modern approaches that respond to the citizens' needs and secures their inclusion. For example, the action plan of Agadir city elected council highlighted important articles from the constitution that called for participation of citizens in the decision-making process.It provided clear statistics of the current situation in all related fields with highlighting objectives to improve it. The language used in the action plan is very simple and represents the participatory approach. Some examples of terms mostly used are: Need assessment, participatory approach, inclusion, participation, governance and communication, constitution, and citizenship budget.The commune called for public consultation meetings where they meet with people from the neighbourhoods to discuss their needs and take their inputs regarding the action plan of the commune from 2023 to 2028. In this regard, the commune organised thematic meetings with various stakeholders to enrich the action plan with the exact need of each sector. The action plan includes a very detailed need assessment that is developed from public consultation meetings with civil society and stakeholders. Furthermore, citizens and associations are invited to facilitate

and manage sports facilities owned by the commune. They called for establishing committees in neighbouring countries for consultation and exchange of sustainable project ideas.

3 PARTICIPATORY APPROACHES TO SOCIAL DEVELOPMENT AND BEHAVIOURAL CHANGE

There are several participatory approaches that can be adopted by public institutions to secure integration of citizens in the development process. Human Centred Design Thinking is one of them. It is the core approach for CorpsAfrica/Maroc to design and implement the community projects. All volunteers are trained and equipped with the needed skills in design thinking to be able to succeed in their service. The experience provided by CorpsAfrica to its volunteers during pre-service training on design thinking and during in-service experience has a clear impact on the volunteer's mindset. Overall, the design thinking approach is not only guiding NGOs to better define people's needs and come up with social innovative ideas but also changes the mindsets of youth to become more solution-oriented (Brown, T & Wyatt, J. 2010). The experience of CorpsAfrica is believed to be a win-win situation where volunteers develop their professional and life skills on one hand and serve needy communities on the other hand. The president of CorpsAfrica/Maroc stated that "The organisation is aware of poverty and challenges in rural areas where volunteers are placed but they are more into finding solutions in a collaborative way with people of the community (CorpsAfrica/Maroc 2022). The main strength of the design thinking approach is that the three phases do not always proceed in a linear manner. However, it is usually started with inspiration which is mainly about empathising with the people and living their lives to understand and identify their needs (Brown, T & Wyatt, J. 2010). Second, there is the ideation phase which is where you assist the community people in challenging themselves to come up with alternative ideas and solutions. The most important volunteer takeaway from experience is humanity. The project does not happen through volunteers but through them. They work as facilitators and give ownership to the local people (Ideagen Global, 2022). CorpsAfrica/Maroc has a clear impact on communities where volunteers serve for a year. The most important is that the organisation spreads values of team spirit, solution-oriented mindset, problem-solving, and innovation. Furthermore, the organisation works on helping people in these communities find solutions by themselves. Humanity is a major idea for CorpsAfrica in general. Building trust between volunteers and their communities is our priority. It takes time especially since trust in Morocco is very valuable (Seilstad, B. (2022). The communities must contribute 25% of the total budget of each implementing project which secures sustainability and gives the ownership of the people of the community. "Local people helping locals rather than outside savers coming in. Our projects are small scale, but high impact" (Ideagen Global, 2022). They also had to contribute with their ideas to identify needs and come up with solutions. After the success of this approach in Morocco that allowed the change of individuals and groups behaviours, CorpsAfrica expanded its work to 10 African countries.

These modern approaches seek not only the contribution of civil society with its various meanings but the inclusion of all stakeholders of the community in the decision-making process. Therefore, these alternative approaches have been developed and adopted to centralise the citizens in the decision-making process. Yet, there is a clear movement to a more horizontal management approach, especially to local affairs that focuses on building grassroots policies that respond clearly to citizens' needs. As a result, participatory democracy appeared as an additional concept of inclusion to replace representative democracy. The concept of participatory democracy comes to secure the inclusion of citizens not just at the implementation level but at all levels of policy-making processes and project development phases. Through this approach, citizens participate in the preparation, management, and implementation of local development projects. Furthermore, their main responsibility is securing monitoring and evaluation of public policies. The concept of participatory is the key term that switched the traditional role of citizens in the classical representative democracy that ends after citizens votes for their representative to a new role where they practise their rights of being part of the decision-making process and feel the ownership of their community projects.

The constitution enabled civil society to make legislative proposals, submit petitions, and be encouraged to be members of municipalities' consultative councils (Touhtou, 2014). Through its various forms of civil society including associations, non-governmental organisations, and social actors, Morocco's civil society has historically played a vital role in shaping public policies and influencing important decision-making processes. Their role as mediators and counterbalance of power helped to secure the interest of minorities.

Furthermore, it helped to make their voices heard. Civil society played an important role in providing feedback to the government in forming policies and enhancing working practices. Most importantly, civil society has been involved in the constitutional reform of Morocco in contrast to previous reforms, where only political parties and unions were involved. This was the first step of civil society inclusion in the decision-making process. The Moroccan civil society after the reforming of the constitution in 2011 with a clear vision towards a new political approach of leadership, their role has become more important likewise political parties. Their participation is a big sign to participatory democracy. They become able to decide about their local development and the way they want to see their cities.

Several theories see that democracy can serve beyond a form of governance where parties gain legitimacy to represent the citizens after the elections. The elite with huge support by Mosca and Pareto views democracy as a regime that secures the elites to govern and represent the rest of the citizens. They emphasise that democracy is when elites rule and the masses follow. According to them, the rule of citizens ends when they vote for their representative (Kolegar, 1967). In contrast, participatory democracy believers argue that the concept of participatory democracy is a progressive democracy that leads to the inclusion of citizens in the decision-making process. This theory allows the citizens to decide about matters that concern them. Governments with a participatory approach see the inclusion of citizens as a priority, not a choice. Debates over the participatory democracy approach become more intense and become a global concern for policymakers. Yet, it witnessed a new movement toward the concept of participatory democracy at different levels of policymaking. This movement was led by several authors such as Barber and Carole Pateman who debated the inclusion of citizens in decision-making as a big sign of participatory democracy (Held, 2006). Until that time, citizens' rule was considered to be limited to voting and after that, public decision-making was given to elected politicians. Social participation thinkers on the other side see citizens to be centred in the public decision-making process. For them, citizens should be involved in all phases of decision-making processes. In his book Participation and Democratic Theory, published in 1970, Carole discussed the educational role of participation (Pateman, 1970). Pateman is inspired by Rousseau who argues that citizens through participatory democracy learn to put public interests beyond their personal interests while Pateman considers individuals learn through a participatory approach that both private and public concerns go together hand in hand since both are related. He suggests that democracy can be established when citizens are fully engaged and participate in the learning process. Most importantly, Pateman argues that participation starts at the local level where people in small communities govern themselves. Local communities govern themselves following traditional and cultural principles that allow the contribution of all in decision-making. This can be a practice for effective political participation (Pateman, 2012). This paragraph aims to highlight the level of understanding and implication of elected councils to the participatory democracy mechanisms in Morocco. Analysing Agadir city action plan, we can notice that their plan is very strong when it comes to the language use of terms related to participatory democracy. This shows the level of understanding of the constitution articles besides organisational laws by the elected members and teams who worked on developing the action plan. In addition to that, the Agadir action plan is well organised giving priority to people with disabilities, associations in managing public facilities, creation of neighbours' committees for sustainable project ideas, climate change and protection of the environment.

4 REGIONALIZATION IN MOROCCO: EMPOWERING LOCAL COMMUNITIES IN CITY DEVELOPMENT DECISIONS

When King Mohamed VI took the throne, he reviewed the regionalisation reforms to rise to the challenge of building a democratic modern state while liberalising the economy (Moyano, 2001). The King gave two speeches setting out the new roadmap of regionalisation, the first one in 2008 and the second in 2010, giving birth to the third wave of regionalisation. This new vision of regionalisation was highlighted by the 2011 constitution as a strategic choice and a lever of change for the future. In 2015, Morocco was divided into twelve regions and the latter were given more financial resources and a broader capacity of decision-making and implementation. Compared to the previous regionalisation efforts, the 2015 regionalisation laws have succeeded in accommodating advanced elements of local democracy (Abdi, 2020). Opposition political parties considered decentralisation as an opportunity to expand their structures at the local level and gain more rents (worldbank, 2009). After the Arab spring, regionalisation was a pressing project that must be implemented. It was an inevitable path towards achieving development and was shaped as a promise to meet the social and economic demands of the people. The guiding principles of the 2015 regionalisation laws were

designed by the consultative commission on regionalisation created in 2010, which included: giving executive powers to the regional councils while alleviating control and tutelage of the Ministry of the interior, implementing participatory democracy and gender equality principles, and enhancing the performance of local governance through integrated development planning and implementation (CCR, 2014).

5 CONCLUSION

All in all, building smart cities in Africa can take a longer process for success. The behavioural aspect of individuals and groups is a big challenge, therefore, the decision maker's need to take into consideration applying participatory approaches in leading change. Among these approaches is Human Centred Design Thinking that allows the opportunity for individuals and groups to lead the change by themselves. This approach secures citizens not to resist the change, sustains the projects and allows innovation and collective work.

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Nature-based Solutions als Aspekt bei der Entwicklung innerstädtischer, hochfrequentierter Parkanlagen am Beispiel Rennbahnpark Frankfurt und Neckarvorland Mannheim

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1 ABSTRACT

Freiflächen im Sinne von nicht bebauten Flächen im urbanen Raum bieten das Potenzial, wertvolle Beiträge zur Erhöhung der Klimaresilienz von Städten und deren ökologischer Funktionsfähigkeit zu leisten. Gleichzeitig übernehmen diese Räume wichtige funktionale Aufgaben, bieten Begegnungs- und Bewegungsangebote für ein breites Spektrum der Stadtgesellschaft und prägen letztendlich auch das Bild von Städten. Zielkonflikte sind bei dieser Vielzahl an Anforderungen die Regel. Anhand von zwei Fallbeispielen (Rennbahnpark Frankfurt, Neckarvorland Mannheim) soll aufgezeigt werden, wie unter Berücksichtigung naturbasierter Planungsansätze diese Zielkonflikte reduziert und hochfrequentierte innerstädtische Parkanlagen entwickelt werden können.

Open spaces in the sense of undeveloped areas in urban areas offer the potenzial to make valuable contributions to increase the climate resilience of cities and their ecological functionality. At the same time, these spaces take on important functional tasks, offer meeting and exercise opportunities for a broad spectrum of urban societies and ultimately also shape the image of cities. Conflicting goals are the rule with this multitude of requirements. Two case studies (RennbahnparkFrankfurt, Neckarvorland Mannheim) will be used to show how, taking into account nature-based planning approaches, these conflicting goals can be reduced and highly frequented inner-city parks can be developed.

Keywords: Planung, Freiflächen, Biodiversität, Klimaresilienz, Parkanlagen

2 RENNBAHNPARK FRANKFURT

2.1 Konzept

Der Frankfurter Rennbahnpark hat eine Größe von ca. 10 ha und befindet sich auf dem ehemaligen Galopprennbahn- und Golfplatzgelände in Niederrad. Aufgrund der Nähe zum Frankfurter Grüngürtel am Rand des Stadtwaldes ist das Gelände Teil eines großflächigen Grünflächenverbundes und als Landschaftsschutzgebiet ausgewiesen. Zudem konnten sich über die Jahre schützenswerte Sandmagerrasen entwickeln. Aufgrund des hohen Nutzungsdrucks augrund der dichten Bebauung im Umfeld, entschloss sich die Stadt Frankfurt, einen großen Teil des Geländes als öffentlichen Park umzugestalten unter der Prämisse, die ökologischen Qualitäten zu erhalten und weiterzuentwickeln. Zentrale Aspekte des Entwurfes sind neben der Schaffung von Erholungsqualität die Themen Nachhaltigkeit, Ressourcenschonung, Entwicklung der vorhandenen Biodiversität sowie Klimaresilienz.

Abb. 1: Rennbahnpark Frankfurt im Frühjahr 2023: Eingebettet in den dicht bebauten Stadtraum (Foto: N. Benner)

Flächen mit Angeboten für Erholung und Freizeit wurden untereinander verknüpft und ihre Funktion mit dem Erhalt und der Entwicklung ökologisch wertvoller Flächen und dem urbanen Naturerlebnis kombiniert. So entstand eine ästhetische Einheit mit vielfältigen Freiraumangeboten, die das Areal zu einem besonderen Parktypus werden ließen. Die landschaftlichen und ökologischen Qualitäten des Ortes spiegeln sich in einer besonderen Struktur und Gestaltsprache des Parks wider. Leitidee war, den Raum in drei ablesbare Zonen mit differenzierten Nutzungen zu gliedern: der ruhige Waldsaum, der Bereich der ehemaligen Rennbahnfläche und die große naturnahe Wiesenfläche mit den Magerrasenflächen im Zentrum.

2.2 Vegetationsentwicklung

Die Zone 1 (Waldsaum) wurde in seiner Grundstruktur weitgehend erhalten und nur durch ein behutsame, auf den Baumbestand achtende Wegeführung erschlossen. In Zone 2 (Rennbahnflächen) wurden großflächige Wiesen angesäht und zahlreiche, zum Teil schnellwüchsige Sträucher und Bäume gepflanzt, die bereits unmittelbar nach der Eröffnung die Grundstruktur des Parks und die räumliche Zonierung vorgeben. Einzelne Baum- und Straucharten sind langlebiger und entwickeln die Struktur langfristig. Sie übernehmen so die Raumbildung, sorgen für Schatten und prägen das Erscheinungsbild des Parks in den nächsten Jahrzehnten.

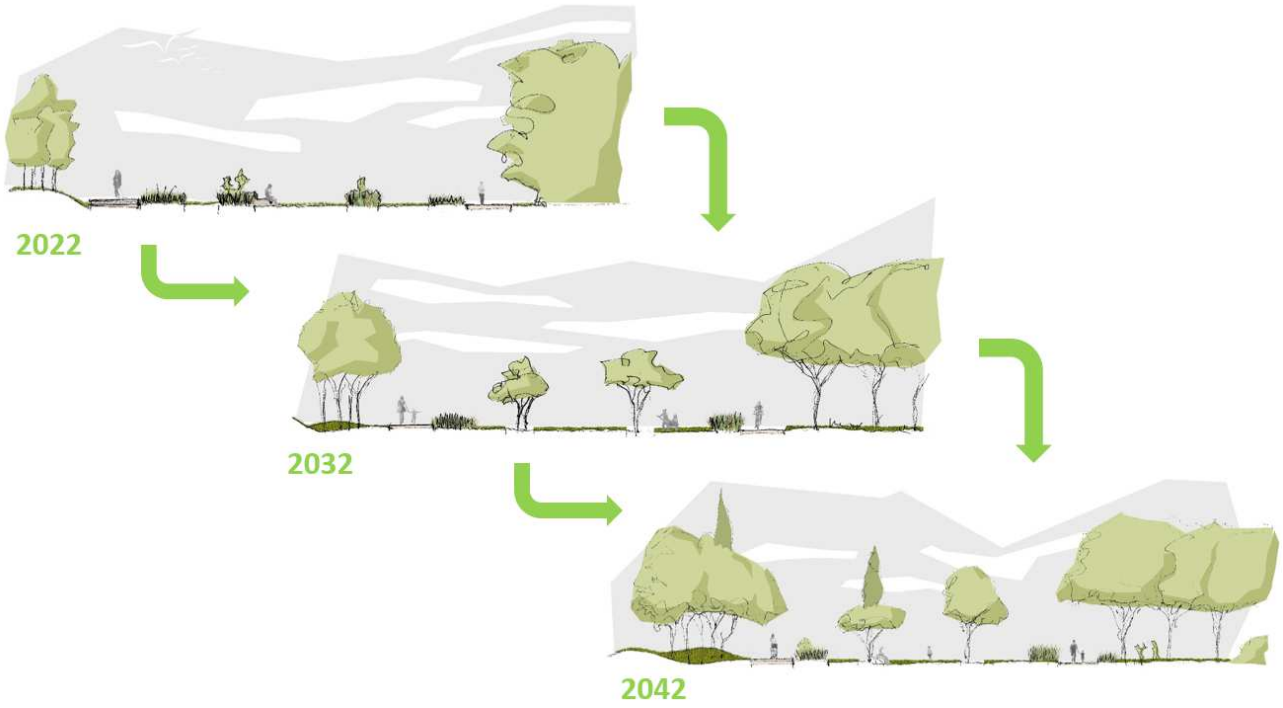

Abb. 2: Prinzip der Vegetationsdynamik in Zone 2 (ehemalige Rennbahnfläche) (Darstellung bhmp)

Insgesamt stand die Ausrichtung des Parks nach Aspekten des Arten- und Biotopschutzes im Sinne einer dynamischen Entwicklung im Fokus der Planung. So wurden die vorhandenen Sandmagerrasenflächen in Zone 3 (ehemaliger Golfplatz) in die Neugestaltung einbezogen. Neue Sandmagerrasenflächen wurden mit Hilfe von Mähgutübertragung etabliert. Die Wiesenflächen wurden durch ein nachhaltiges und hinsichtlich klimatischer Aspekte zukunftsfähiges Pflanzkonzept, u.a. mit schattenspenden Baumpflanzungen, ergänzt. Die Vegetationsentwicklung wird u.a. durch ein Beweidungskonzept unterstützt und durch ein Monitoring begleitet.

Auch dient die Parkfläche der Kaltluftentstehung und reduziert die Hitzebelastung. Zudem wurde Wert auf ein Minimalmaß an versiegelten Flächen gelegt. Das Niederschlagswasser der versiegelten Flächen wird in die Vegetationsflächen eingeleitet und dient der Bewässerung. Die großzügige Teichfläche, in Form einer offenen Wasserfläche sorgt für zudem für Kühlung an warmen Sommertagen.

Abb. 3: Beweidung der Sandmagerrasenflächen in Zone 3 (ehemaliger Golfplatz) (Foto: N. Benner)

2.3 Beteiligungsprozesse

Im Sinne einer sozialen Nachhaltigkeit spielten Beteiligungsprozesse und Entwicklungsprozesse eine wesentliche Rolle bei der Grundkonzeption des Rennbahnparks. Schon frühzeitig wurden Bürgerinnen und Bürger an der zukünftigen Gestaltung des Parks beteiligt, konnten Ideen, Ängste und Fragen äußern und so Einfluss auf die Gestaltung des Parks nehmen. Auch Kinder und Jugendliche hatten bei zahlreichen Workshops Gelegenheit ihre Wünsche für den Spiel- und Sportbereich vorzutragen und in Form von kleinen Modellen zu verdeutlichen. Zudem wurden zahlreiche Interessensgruppen am Planungs- und Umsetzungsprozess beteiligt.

Aber auch zukünftige Prozesse, wie beispielsweise das Beweidungskonzept oder die Beteiligung der Bevölkerung an der Entwicklung einer Jugendfarm werden die Entwicklung des neuen Rennbahnparks prägen.

3 NECKARVORLAND MANNHEIM

3.1 Konzept

Der Neckar ist mit seinen Ufern wichtiger Bestandteil der Grün- und Freiraumstruktur der Stadt Mannheim. Im Stadtteil Neckarstadt-West besteht ein erhebliches Defizit an öffentlich nutzbaren Grün- und Freiflächen. Das Neckarvorland mit einer Größe von ca. 11 ha ist heute kaum strukturiert, mit wenigen Zugängen und Nutzungsangeboten für die Bürgerschaft und beschränkten Qualitäten für die Stadtnatur in Mannheim. Gleichzeitig ist die Weite und Offenheit der Wiesenaue eine erhaltenswerte Qualität inmitten der Dichte der Stadt. Auch der direkte Bezug zum Neckar bietet ein großes Potenzial für eine nachhaltige Entwicklung.

Abb. 4: Das Neckarvorland im Sommer 2022: funktionale, für den Wasserabfluss optimierte Gestaltung (Foto: R. Bentley)

Das Ziel, Freizeit- und Erholungsangebote mit dem Natur- und auch Hochwasserschutz zu verbinden, wird dabei nicht als Restriktion, sondern als Chance verstanden, um für diesen besonderen Ort einen urbanen Freiraum mit ganz eigenem Charakter und Identität zu entwickeln. Aus den Qualitäten und Herausforderungen des Ortes kann ein Raum gestaltet werden, der mehr Naherholungsbedürfnisse erfüllt, den Neckar erreichbarer macht und gleichzeitig Raum für die Entwicklung einer Stadtnatur schafft. Dadurch werden nicht nur die Wohnqualitäten der Neckarstadt-West gestärkt, sondern auch die Identität des Quartiers.

Abb. 5: Darstellung Zielzustand Neckarvorland (Darstellung: filon)

3.2 Vegetationsentwicklung

Grundlage der Entwicklung der Parklandschaft ist ein differenziertes Vegetationskonzept. Es schafft Bereiche mit unterschiedlichen Vegetationstypen. Durch die Nutzungslenkung können auch größere Flächen vorrangig Naturschutzfunktionen übernehmen. Dies sind im wesentlichen artenreiche Wiesengesellschaften mit Gehölz- und Baumpflanzungen. Durch die Topografie und die Nutzung von Regenwasser werden Bereiche unterschiedlicher Bodenfeuchte mit entsprechend angepasster Vegetation geschaffen. Die großen Wiesenflächen mit aktuell geringem ökologischem Wert werden damit ökologisch aufgewertet.

Abb. 6: Biotopwertigkeit Bestand und Zielzustand (rot = sehr gering; gelb = gering; hellgrün = mittel; dunkelgrün = doch) (Darstellung: bhmp)

So wird der Schutzzweck des Landschaftsschutzgebietes (Förderung, Erhaltung und die Wiederherstellung erholungswirksamer Landschaftsstrukturen und ihrer Zugänglichkeit und Nutzbarkeit für die Allgemeinheit) erreicht. Dabei wird die Vegetationsentwicklung auch durch ein spezielles Nutzungs- und Pflegemanagement unterstützt. So entsteht eine Mosaik unterschiedlicher nutzbarer Vegetationsstrukturen. Es bildet verschiedene Habitate aus und integriert dabei auch Aspekte des Regenwassermanagements im Sinne einer klimaresilienten, Ressourcen schonenden und die Belange der Artenvielfalt berücksichtigenden Stadtentwicklung.

Abb. 7: Stromtalwiesen als potenzielle Spenderflächen für die Mähgutübertragung (Foto: J. Bresch)

3.3 Hochwasserresilienz

Um die Auswirkungen der Planung auf den Hochwasserabfluss im Neckar zu prüfen, wurde vom Institut für Wasser und Gewässerentwicklung des KIT (Karlsruher Institut für Technologie) eine 2D-HN-Strömungssimulation erstellt und in einem iterativen Prozess die Planung im Hinblick auf eine Hochwasserresilienz optimiert.

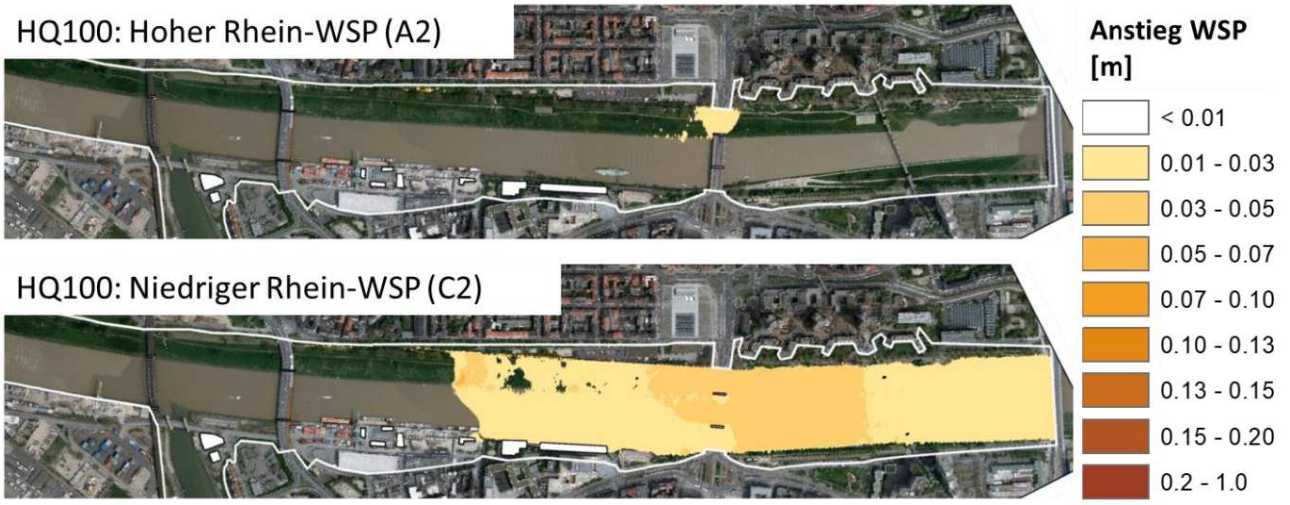

Abb. 8: Flächiger Wasserspiegelanstieg zweier Szenarien: Vergleich Plan-Zustand mit dem jeweiligen Ist-Zustand (Foto: J. Bresch)

4 CONCLUSION

Mit einer urban-ökologischen Ausrichtung wurde bei den Fallbeispielen Rennbahnpark Frankfurt und Neckarvorland Manneheim versucht, eine Antwort zu geben auf die Frage, wie in innerstädtischen Parkanlagen die Zielkonflikte zwischen Nutzerinnen- und Nutzerbedürfnissen, Stadtklimaresilienz sowie Arten- und Biotopschutz reduziert werden können. Erste Beobachtungen im Rennbahnpark sind

grundsätzlich vielversprechend. Inwieweit die Ziele auch mittel- bis langfristig erreicht werden können, wird das begleitende Monitoring zeigen.

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ODD – Operational Design Domain as Test Arrangement for the Future Automatisation of Road Traffic

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1 ABSTRACT

Following contribution refers to preceding results presented in German at CORP 2019 and CORP 2020 on the issue how automatization will change and shape future mobility. Some recent knowledge of our work should be a topic for further critical discussion about technical progress triggered by automotive industries. However, are we as planners from the outside prepared for that?

Within the year 2024, the equipment of new vehicles with ADAS (Advanced Driving Assistance Systems) will be obligatory by law. Have been such applications according to automation grade 3 efficient proved in respect of daily road traffic? Who can give answers to new cars assessment of it? One of the proving approaches are so-called Operational Design Domains (ODD). A professional guideline defines an ODD as "operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics." ODD is the design domain of an ADAS or a feature thereof with respect to its operation." This approach can serve as a strategic instrument to prepare the implementation of autonomous driving via the automatization of road traffic into the mobility system on the long view. Now, what tasks of testing activities are required?

- Testing technical efficiency of relevant instruments (off-road)
- Finding practical insufficiencies of functionalities based on test arrangements (on test grounds)
- System proving of driving practice (feasibility-check on-road)
- Authorization of vehicle´s types (reliability- and safety-checks)
- Adaptions of road-network for automatization of road traffic (as task by road providers)
- Assessment of sociability in settlement areas (need of regional regulations in urban road spaces)

Therefore, a broad field of interrogative activities ought to have done before a deployment of highly automated or even autonomous moving vehicles penetrates the markets. If they reach a considerable amount within the car´s stock, it might be too late for assessment studies. "We will look what would happen" as negligent political strategy seems indolent facing the historical developed miscellaneous road network in Europe, which somewhere lacks of large scale in comparison with America´s grid of streets and highways.

Automatization of cars deals with a manifold topic driven by automotive industrial progress using hard- and software tools of digitalization, automatization and interconnectivity.

The topic, what technical support needs automatization of road operations, stands at the very beginning of the discourse about future motorized mobility. At first, we focus the view on a vehicle as moving body flowing in traffic and interacting with other traffic participants. Dependent on automation-grade of vehicle´s stock different with automat-functionalities equipped cars are objects for testing arrangements (Fig. 1). Pure technical capacities and the reliability of quality to cope with a certain functional task are next to prove. That represents the view into the car, though it effects outside other traffic participants. On the contrary, a bird´s eye-view on the cars flowing onto carriageways represents the complementary view (Fig. 3). These antagonistic views on the automatization of motor vehicles unveils possibly weaknesses of the usage of technologies hardware-side, like sensors for detection of open paths (Fig. 2), and software-side, where signals are processed to car-inherent scenarios. Bearers of homologation of single functionalities ought to complement their proving by holistic arrangements aiming at the car-inherent system architecture to evaluate the effects affecting other road users in respect of its personal integrity and safety (Fig. 5).

Keywords: road traffic, test proceedings, urban planning, ODD, ADAS

2 ADVANCED DRIVING ASSISTANCE SYSTEMS (ADAS) AS AN AUTOMAT-CHAIN

ADAS as driver´s supporting functionalities for cruise control concern speed limitation, distance keeping, lane keeping, overtaking assistance, death angle warning, parking manoeuvers and other useful tasks. While responsibility for driving actions remains to the driver who has to be present fully, but a deskilling of routine may affect drivers, who trust too much in ADAS. Then ADAS in general fulfil simple tasks as divided effective functions, which are not able to generate a complex driving scenario as base for controlling the car autonomously. Anyhow, ADAS can be useful as risk reducing and traffic modulating instruments to cut extremities of driving-manoeuvers. As reminder, we have to do with human beings sometimes suspected as source of insecurity on the roadway. How to ensure human needs for an anxious free mobility for all traffic participants, if motorized or not? On the other hand, how to retain sovereignty of car-holders over its vehicles but without to be responsible for malfunctions of automatization tools?

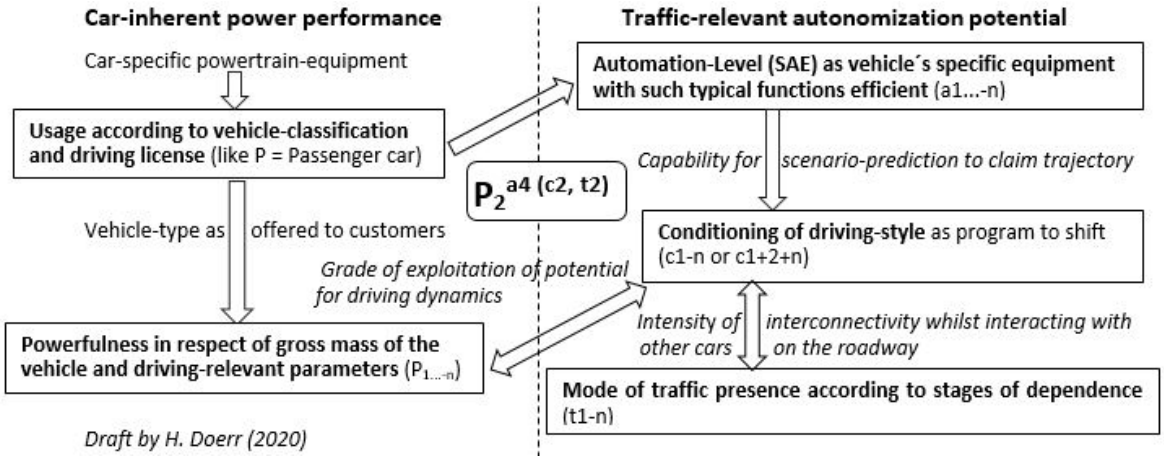

Figure 1: Vehicle´s potential for autonomization connecting power performance with automation functions

The functionalities of automation are arranged as an operative chain being vehicle-inherent installed and possibly external supported. Each of them fulfils tasks step-by-step as there are:

2.1 Detection of open fields by sensory technologies

The sensors detect open trajectory spaces on the pathway (Fig. 2). The interpretation of signals has to find out what obstacles or interventions might threaten. That includes behavioural estimations of what opponents involved in interactions or other living beings could bring about. Sensory technologies, as LiDAR, Ultrasonic or simple Camera-Viewes, deliver different prospections, so that a equalizing by data-fusion-software between them is required. This fusion of data either internally detected, externally fed or already inherent deposited under some rules of vehicle-side typical conditioning shaped by the manufactures prepares decision-making for claiming the best trajectory. That seems the crucial point within the automat chain, how data are weighted and input in decision-preparing algorithms.

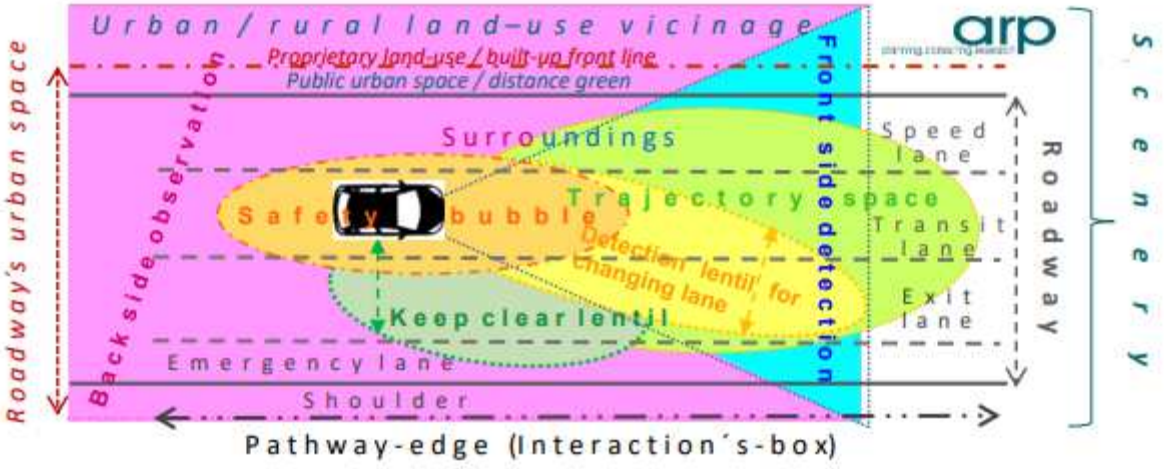

Figure 2: Fields of vision detected by a solitary car to claim a trajectory onto his pathway

2.2 Scene prospection and scenario construction

The scene prospection depends on proposed driving manoeuvres, like overtaking other cars, turning the direction or changing the lanes. It contains not only the car-own options but the expected options of opponents too. Then a scenario construction can follow whereabouts interactions between traffic participants, like vehicles as opponents and other not-motorized or weakly supported actors like cyclists or pedestrians, would take place. That car-inherent construction of scenarios leads to a decision, what of the options to pave one´s way would be the best. A scenario as option of handling car´s drive consists of logical connected driving manoeuvers as steps to move forward. We have to consider that automated decision-making needs a permanent processing to claim an optimal trajectory for the next seconds of driving on the roadway. Therefore, it deals with a permanent processing in a chain of decisive control mastering hidden in the backend of the car-inherent automatic chain. That sounds complex in theory and views complicate in road traffic practice. At that, a car-typical conditioning-software has to evaluate in the background a selection of driving options as far as such behavioural strategies are not deeply standardized by general automotive specifications. If a car-driver might select one of a sample of driving styles for an intended route, then economic (to be in rush), ecologic (emission-reduced ride) or ethic (considerateness against vulnerable others) motives stand in the fore. For instance in the way that a downgrading (a++ to a+) of automat-potencies is available (Fig. 3). Sometimes it may be also that the driver will enjoy the ride by steering oneself.

2.3 Commands for driving manoeuvers

Driving manoeuvers need commands to the steering chassis and the powertrain of the vehicle. Each of the several commands to realize driving manoeuvers requires a calibration of tracking the right trajectory according to power and velocity parameters suitable to the taken pathway. Moreover, “an exit strategy” for surprising events is not to forget. That leads in a cascade of challenges for software developers to master complexity of boundary conditions and insecurity in respect of peculiar behaviours of adjacent opponents. Because roadway´s traffic does not work like an industrial production line. If at some time artificial intelligence would take over responsibility for handling the car from humans, then a part of that “brain” should be a module of ethic conscience as modulator of car-typical power mightiness to prevent careless or dangerous driving actions. We call that “Conditioning” of the car-inherent automotive chain of high-automated vehicles from SAE-Level 3 (= highly assisted driving as recent standard) upwards. SAE-Level 4 would enable a car to move partly autonomous, if the pathway allows it, but a driver is present in the car. Level 5 means, that the vehicle moves driverless and even without any passengers on board.

3 OPERATIONAL DESIGN DOMAINS (ODD)

3.1 Methodic Remarks

ODD defines a test location according to a relevant scenery. The testing institution has to formulate a test program in the direction, what tasks of vehicle´s automation are to prove. If results of testing are available, ODD could serve as a warning method to prevent some system-immanent mistakes, if systematic grounded as pretesting instrument. That proceeding can perform as a missing link between automotive software-hardware developers and traffic planning resp. road constructing engineers, if the latter professionals are involved in the selection of test sections and embedded in the definition of testing tasks. In such a way, both world of expertise could connect their interrogative interests to gain more knowledge about automated operations on road. A multitude of boundary conditions, as exogenous preconditions fixed, like roadway´s infrastructure and local regulations, or as external conditions limiting the freedom of driving, for instance as timely traffic jams or bad weather. Referring to urban and regional planning following issues are considerable, although these have not been key questions of spatial planning yet. Like zoning areas due to landuse in the vicinage, wherein vehicle´s operations of higher automation levels should be either admitted or restricted. Secondly, traffic planning could select proper sections within the road-net, where the usage of certain functionalities is allowed or ordered obligatory. Thinking about required duration of working out a mobility plan (2-3 years) and its realization (+/-10 years), it seems not too early to engage with such ticklish topics. Otherwise, technical progress might overrun planning processes and political decision-making .

3.2 Basic database for construction of scenarios

Making scenario construction operative to the automat-chain of an autonomized car there will be a need of systematic categorization of relevant subjects, of which characteristics and attributes more or less are suited to master challenging tasks of automatized driving. As they are (maybe in an incomplete listing):

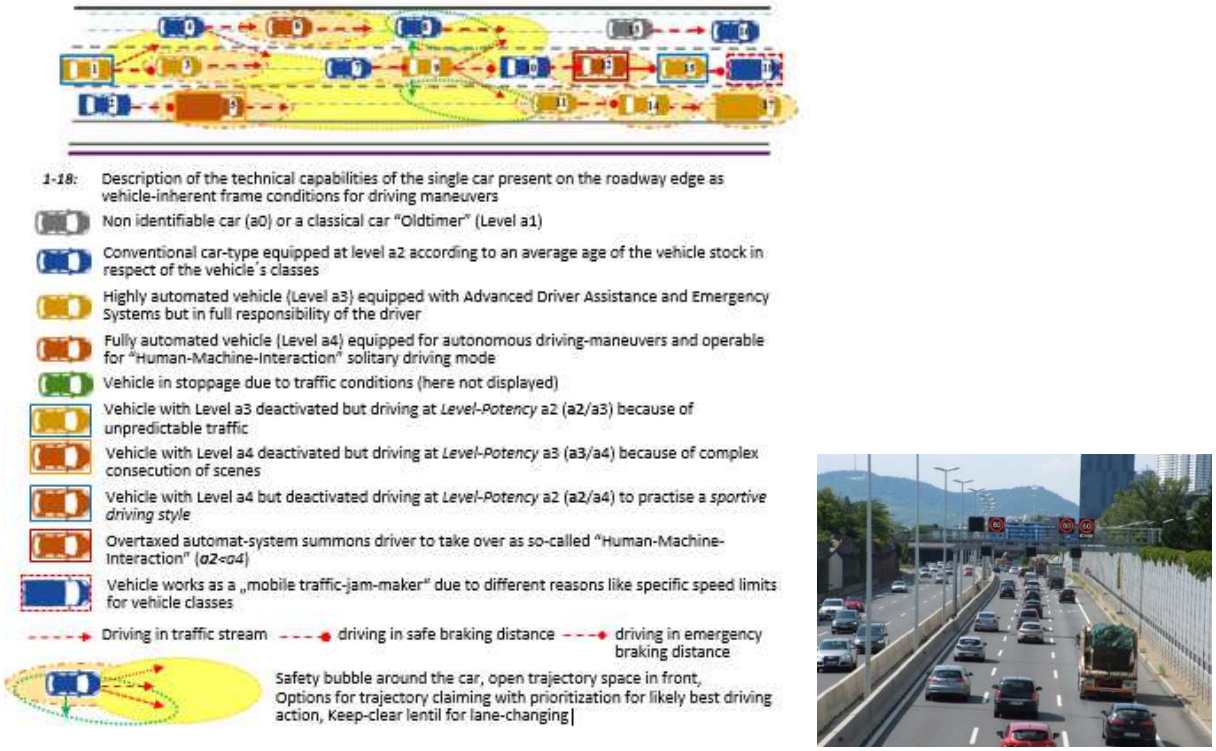

Figure 3: Construction of a scenario field onto a three-lane carriageway of Danube-Embankment-Highway (A22) in Vienna as scenery. The section shows a mixture of vehicles typical for urban traffic.

This scenario “Mixed vehicle traffic onto a 3-lanes carriageway” bases on the assumption that each vehicle shows its own specific characteristic of motor power and automat-level. It seems to be the most realistic as well as the most complex scenario of partly automated road traffic under the rule of indiscriminate traffic participation of motorists. All the vehicles behave as solitary moving actors. Such a mixture of cars causes a heterogeneous nearly unpredictable traffic flow. Hence, the prevention of critical interactions stands in focus.

List of useful databases for drafting ODDs:

- Vehicle´s automation equipment corresponding to the SAE-levels
- Vehicle´s motorization corresponding to vehicle utility classes and automotive brands
- Roadway´s tracing characteristics embedded in the landscape
- Roadway infrastructure to master typical traffic function within the road network
- Roadway surrounding tract in respect of traffic generating land uses and external intervening risks
- Rhythm of daily traffic flows occurring onto sections of the road network
- Local caused circumstances by the natural environment and the built-up area
- List of mobile groups of traffic participants with their movement behaviours and handicaps
- List of vulnerable road users and their special safety needs
- List of supporting means of moving which are not or weakly motorized (like e-scooter)
- Standardized scenes of driving manoeuvers as they can be often observed
- Systematization of interactions between traffic participants (“opponents”)

Driving manoeuvers and traffic interactions between vehicles or with other road users have several formal dimensions measured as frequency and estimated as likelihood, if actions are operable defined. The localisation of them over the road net is crucial to identify critical interaction boxes and critical interaction´s

relations between members of different mobility groups. Its interactions on roadways distinguishes by a broad variability of the participants mix and their driving habits. That´s why no interactions within a short-time lasting and dynamic "Sailing Interactions Space" are exactly predictable (Fig. 5).

3.3 Some approaches to draft an ODD

Drafting an ODD depends on what results the testing institutions expect by the test arrangements. In general, a technical assessment stands in the foreground, when possible effects of vehicle´s automatization meet sensitivities of other traffic participants, here so called "opponents" involved in interactions as tribute to the Gaming theory. Furthermore, beyond single traffic interactions onto roadways, automated movements of vehicles could affect potentially the interests of inhabitants of surrounding urban places (Fig. 2).

3.3.1 ODD by urban sceneries as preconditions

Urbanist´s interests concern a multitude of issues referring to quality of urban life. Therefore, it means to beware and to optimize environmental conditions in coexistence with economical requirements and its traffic needs. Consequently, such an approach focuses on the effects of vehicle´s automatization in both direction, what of the equipment of cars in interconnection with roadway´s infrastructure will be useful and what usage of car-inherent functionalites might be contraproductive in specific sceneries of urban traffic events. Within this context, town- and traffic-planning has to define its part, which will be not only an enduring one as a passive observer. Nevertheless, such technological driven changes in automotive equipments are sneaking processes and the penetration into vehicles stock is hitherto not on record. Any problems occurring become obvious for the first time in traffic statistics, if accidents accumulates somewhere. Sceneries as key approach to provide an ODD are typical urban spaces within the zoning of metropolises in respect of land use patterns and built-up densities. As a starting point serves the gradient of urbanisation, which structures all of our urbanized regions beginning with the core of central and inner urban districts, surrounded by suburban and periurban belts. Each of these urbanized sectors has its typical characteristics and sensitivities as spatial preconditions for traffic events there, which a story telling can describe similar to a script for a movie.

3.3.2 ODD by roadway´s network as spaces of traffic events

A road-network represents a hierarchical order of road categories according to its service functions for open up the vicinage and for ensure traffic capacity needed there. So, "form follows function" as we know from urbanism. Road´s constructive characteristics (number of lanes, traffic surface organisation, traffic flow management and so on) on the one hand and the embedded situation in urban public spaces on the other hand built a framework for car´s driving style and for traffic operations of road providers. The dynamics of driving manoeuvres of different car types, for instance heavy or light vehicles for passenger transport or goods´ deliveries, have to be calibrated as well as the constructive dimensions of roadways for that. As key questions to answer might be, what adaptions for highly automated vehicles operation on the roadside will make sense and what regulations on the side of motor traffic might be necessary. That concerns also modulations of driving dynamics within the car-inherent automat chain to be compatible with the respective roadway category and considerates specific sensitivities of inhabited land use in the surrounding (Fig. 4).

3.3.3 ODD by typical interactions between motorists and other road using groups

In such test cases, road-traffic is seen as participation of all road-using members of mobility groups, who interacts within a typical section of a roadway called as interaction space (Fig. 5). Intersections are the most critical of them, where the participant´s emerging is highly coincidentally and a prediction of its behaviours seems a hardly task for car´s inherent automate chain. Deep learning to gain artificial intelligence has the difficulty that no one of each situations would be the same. Therefore, it might be a question of conditioning the car´s automat system in respect of consideratness – as an ethical pretension – when interacting with more weak opponents. Besides, road traffic planning has mostly done to mitigate conflicts what the urban scenery spatially allows. However, it represents the most complicate, but daily trivial traffic events. Automatization of such interactions are hardly to expect on the short view, because of the complexity of movement habits, which characterize all different mobility groups. If they are motorized or not motorized, free of handicaps or burdend with mobility restrictions, which are not only due to bodily infirmities. Vulnerability of the interacting opponents would be a crucial moment to modulate dynamics of motor vehicles.

3.3.4 ODD by coincidental collectives of vehicles

Promotors of further automatization of road traffic tend towards to put a home play among motorists on the stage. Carriageways with three lanes along motorways out of town are actually the preferred ODD to test automated driving manoeuvres like distance keeping, speed control or over-taking actions. A crucial issue would be to put up a realistic mixture of different equipped vehicles on different levels of automatization (Fig. 3). That calls for a coordination by means of interconnectivity as well as for a right-time traffic management by the road-operating provider according to current traffic conditions within the road-net.

3.4 Interconnectivity as an asset?

Establishing of interconnectvity between adjacent vehicles makes data-exchange possible for a better coordination of their driving manoeuvers. That means each of the involved cars resp. car-holders has to give up some of its sovereignty for the favour of a collective optimization of moving forwards. Such a collective behaviour as moving bulk of vehicles could effect in more safety and less emissions through harmonization of traffic flow in view of modulating speed and keeping secure distances.

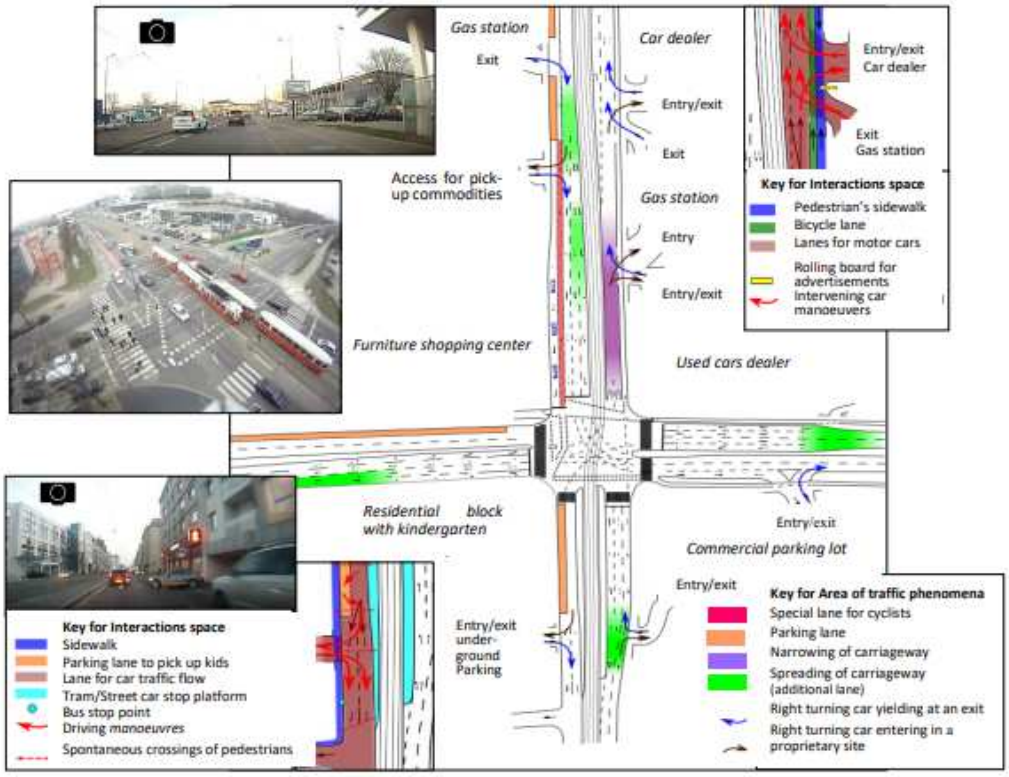

Figure 4: Intervened interactions spaces as phenotypical characteristic of a radial urban trunk road

Mainly we know three applications of interconnectivity:

3.4.1 Vehicle(s) to vehicle(s) (V2V) as motor-traffic internal communication

Car-to-Car-Communication serves as tooling to inform about intended driving actions, to keep distance by controlling the own car or to exchange data for harmonizing movements each another (bilateral or multilateral reactive between for that equipped motor vehicles). In fact, each car acts as a solitary moving body, but with a sufficient consideratness to prevent critical interactions with others. Bilateral V2V-communication concerns actually in interactions “nearfield” involved vehicles and multilateral with opponents within the detection-field (Fig. 2), where trajectory claiming could be touched or even threatened.

3.4.2 Vehicle to Infrastructure (V2I) as motor-traffic external communication

Each vehicle dispatches data of the ride and receives useful information about traffic conditions from the cloud. Thus, it deals with a bidirectional-individualized communication mainly on demand. First, data of car´s operation goes to the automotive manufacturer, who observes in such a way presumably customers as well. Additional a bidirectional data-exchange takes place for the disposition of commercial car-holders active in transport businesses. Nowadays the receiver of orders is the driver, but in a further future the

control system of vehicles might receive steering commands by an external control master. Which one acts dislocated from the car as remote controller maybe supported by artificial intelligence. Proven since decades are traffic light regulated intersections coordinated along urban trunk roads to facilitate an unbroken traffic flow. In a first approach in-coming vehicles can receive a previous information to modulate the approaching velocity. Bidirectional the car makes known to the traffic management the intended directions at the next intersections tracking the route. As further enhancements, the remote traffic management might take over steering of the car instead of the control of a driver present in the car. In times out of traffic rush an ordinary car would ask for green light on demand wireless by air. With that, traffic management has a lot of coordination to do, if a majority of vehicles would be on track in this way. Notwithstanding road providers have to avoid improper discrimination of under-equipped motorists. So we can conclude, that to establish interconnectivity between motor vehicles is technical feasible but in organisational respect full of restraints.

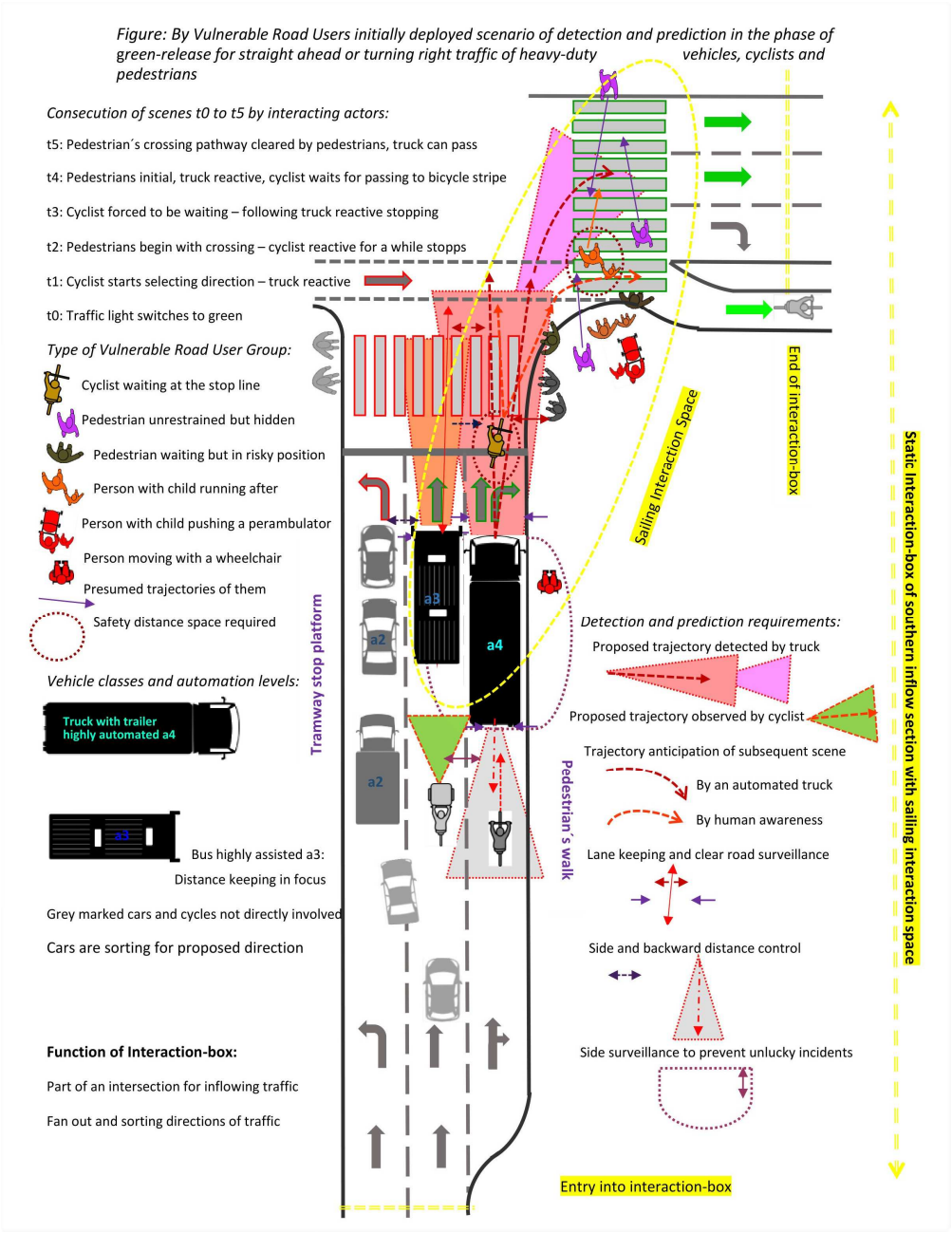

Figure 5: Heavy duty vehicles starting to cross intersection straight ahead and turn right

3.4.3 Vehicle to other traffic participants (V2X) as road-users-relations

It becomes more difficult, if road users of all mobility groups come into play. Among them are not motorized pedestrians, especially vulnerable persons or cyclists, which are extremely occupied by mechanical steering to hold its path. Maybe that all of them have smart phones with them, but would all of them be guided in this

way on the way. Looking on a smart phone´s screen less or more steadily causes stress. The scenario depicted in Figure 5 dealt with the task how an automated driving system would be challenged, if vulnerable road users will be the initial actors on the scene. The short story hereby tells a scenario of interactions between a cyclist as initiative actor at the beginning, a heavy-duty truck as reactive actor and pedestrians as independent co-players. The interactions between them take place in an interaction box as part of an intersection as depicted in Figure 5. The traffic light gives the starting signal when it shows green release for going straight ahead or turning to the right. The initial actor is a cyclist waiting for green light at the stop line while a heavy truck is approaching. The cyclist has two options to direct himself: forwards straight ahead or turning right. If both participants are going for turning towards right, it will be a tremendous challenge for an autonomized heavy vehicle detecting the forefield, predicting the behaviours of the others and controlling his own driving dynamics. This story leads to a setting for test arrangements proving the automatic system of the vehicle based on requirements of the "real world" which cannot be done convincingly by computer simulations.

So, what are practicable solutions to integrate non-motorists into interconnected road traffic operations. They can get messages about general traffic circumstances in the surrounding, what is usual nowadays, if demanded. Smart phone holders can be especially addressed, if target groups with its information needs have been constituted. All applications at the present state of the art effect monodirectional as warning signal, either X2V or V2X, if a critical approaching threatens. Though, such helping instruments are not deployed yet. Therefore, an integration into a system of automated road traffic is not expected for the close future. Nevertheless, a mobility strategy as political guideline for traffic planning has to consider, that instead of integrating non-motorists into automatic traffic operations a forced spatial desintegration within the network of pathways will not be a satiesfying solution.

4 RÉSUMÉ FOR AN OPEN DISCOURSE

Technical progress has its utilities but also weaknesses, which the draft of ODDs can help to unveil as some disadvantages for free mobility. Scenario generating for that means combining static and dynamic recurring frame conditions as rules of an interaction box respectively a "playing ground" with the behaviour of traffic participating players coping with tasks of driving or moving in a consecution of interactions between them. Approaches derived from real world as exemplified do not solve technical problems as that are tasks for automotive research and development. Rather it should help to trace out challenging traffic events and to put up framing conditions, which influence traffic flows exogenously. In such a multidisciplinary manner deficiencies untied from pure technical quality requirements and standardization, like ISO 26262 and as newst ISO 34503-2023 concerning ODD (which have been not discussed here to stay independent), could be revealed. Embedded in a chain of test and implementation procedures all relevant stakeholders, experts and affected groups from the mobility milieu can be addressed. Not at least, because this methodical approaching should enable them to reflect the evoked changes by the arising innovations within the mobility system and to encourage them to contribute their considerations to that in a democratic discourse.

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Regionalisierung von Wohnungsmärkten anhand kleinräumiger Umzugsbewegungen in Deutschland

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1 ABSTRACT

Eine möglichst genaue Regionalisierung von Wohnungsmärkten ist für die Erstellung aussagekräftiger Wohnungsmarktbeobachtungen von zentraler Bedeutung. Oftmals werden in der Praxis administrative Grenzen zur Abgrenzung genutzt, die nicht zwangsläufig den funktionalen Wohnungsmärkten entsprechen. Der vorliegende Beitrag zeigt eine alternative Herangehensweise auf, mit der sich Wohnungsmärkte anhand des tatsächlichen Umzugsverhaltens räumlich abgrenzen lassen. Hierfür werden innerdeutsche Umzugsverflechtungen aus den Jahren 2011 bis 2023 analysiert. Die Umzugsverflechtungen wurden in mehreren deutschlandweit ausgewählten Postleitzahlen mithilfe eines standardisierten Verfahrens kleinräumig ausgewertet und visualisiert.

Die Untersuchungsergebnisse verdeutlichen, dass die kleinräumige Struktur von Wohnungsmärkten in Abhängigkeit von den lokalspezifischen Rahmenbedingungen heterogene Muster aufweist. Dabei zeigt sich, dass neben natürlichen Barrieren auch die soziodemografische Zusammensetzung der Quartiere und die allgemeine Anspannung des lokalen Immobilienmarkts die räumliche Beschaffenheit des jeweiligen Wohnungsmarkts prägen.

Keywords: Planung, Regionalisierung, Verflochtenheitsprinzip, Umzugsbewegungen, Wohnungsmärkte

2 EINLEITUNG

Ein Wohnungsmarkt ist der räumliche Bereich, in dem Haushalte leben und arbeiten, und in dem, bei identischen Lebensumständen, nach alternativen Wohnstätten gesucht wird (Royuela und Vargas, 2009). Nur wenn sich die allgemeine Lebenssituation ändert (z.B. Arbeitsplatzwechsel, Studiumsstart, Scheidung, Renteneintritt usw.), sind Umzüge außerhalb des eigenen Wohnungsmarktes vorstellbar. Unterschiedliche Haushalte haben unterschiedliche Präferenzen bezüglich Pendeldistanz, gewünschter Wohnfläche und Umgebung. Daraus folgt, dass die Definition eines Wohnungsmarktes nur graduell erfolgen kann: Für einen Haushalt gehört der ländliche Suburbanisierungsstandort noch zum Wohnungsmarkt, für einen anderen Haushalt nicht mehr.

Die Beschaffenheit von Wohnungsmärkten ist zudem maßgeblich davon abhängig, aus welchen Gründen umgezogen wird. Einem Umzug kann beispielsweise der Wunsch nach einer anderen Typologie, Wohneigentum, mehr oder weniger Wohnfläche, mehr Grünflächen, geringeren Wohnkosten oder einer besseren Anbindung vorausgehen. Eine Umzugsstudie der Postadress (2021) sammelt Gründe für Umzüge in einem Befragungspanel mit insgesamt 10.000 Personen (davon ca. 10 % im letzten Jahr umgezogen). Am häufigsten wurden hier familiäre Gründe (40 %) genannt. Bezogen auf dieses Arbeitspapier besteht kein Grund zur Annahme, dass sich diese Gründe regional (signifikant) unterscheiden. Stattdessen könnten die Gründe Verbesserung des Wohnumfeldes/-raumes (37 %), veränderter Platzbedarf (28 %) und Verringerung der Kosten (16 %) unterschiedliche regionale Fortzugsmuster hervorrufen.

Administrative Grenzen sind für eine genaue Abgrenzung von Wohnungsmärkten nur bedingt geeignet, da sie zumeist historisch gewachsen sind und die realen Lebensräume nicht ausreichend genau abbilden (Michels und Oberst, 2011). Ein alternativer Ansatz besteht darin, Wohnungsmärkte anhand von Wanderungs- und Pendelverflechtungen zu identifizieren und abzugrenzen. Die Analyse erfolgt hierbei zumeist auf Kreisebene (z. B. Eckey et al., 2006, Michels und Oberst, 2011; Busch, 2016). Michel und Oberst (2011) zeigen am Beispiel von NRW, dass deutlich kleinere (Sub-)Wohnungsmärkte gebildet werden, falls Gemeinden statt Kreisen genutzt werden. In Großstädten könnte die Gemeindeebene zudem nicht ausreichend kleinteilig ausfallen. Es sind auch lokale Wohnungsmärkte vorstellbar, die aus äußeren Stadtteilen und deren Umland bestehen. Um Wohnungsmärkte realitätsnah abzugrenzen, erfordert es somit einer möglichst kleinräumigen Betrachtung. Daher wird im Folgenden eine Betrachtung der Umzugsverflechtungen auf Ebene der Postleitzahlen vorgenommen und Fortzüge anhand mehrerer Beispiele

visualisiert. Aus den Ergebnissen werden allgemeine Hypothesen über die Beschaffenheit von Wohnungsmärkten entwickelt.

3 DATEN UND METHODIK

Für die vorliegende Analyse kann - anders als in den Referenzstudien - auf einen pseudonymisierten Mikrodatensatz mit Umzügen eines Geodatenanbieters zurückgegriffen werden. Der Umzugsdatensatz enthält knapp 38 Millionen Fälle von 2012 bis 2023. Der Datensatz entspricht keiner Vollerhebung, sondern repräsentiert ca. 45 % aller Umzüge im Betrachtungszeitraum. Die im Datensatz vorhandenen Umzugsinformationen werden durch Adressänderungen privater Haushalte generiert, wobei ein Einverständnis zur statistischen Auswertung gegeben sein muss. Auslandsumzüge sind im Datensatz nicht abgebildet.

Als Auswertungsebene wurde die Postleitzahl gewählt. Der große Vorteil von Postleitzahlen gegenüber Gemeinden liegt in der deutlich homogeneren Bevölkerungszahl: In Großstädten existieren mehrere Postleitzahlen (z.B. Frankfurt am Main mit 43 Postleitzahlen), während im ländlichen Raum mehrere Gemeinden sich eine Postleitzahl teilen (z.B. umfasst die Postleitzahl 54662 die Gemeinden Beilingen, Herforst, Philippsheim und Speicher).

Um Wohnungsmärkte zu definieren, sollten Fernumzüge bzw. Umzüge, die durch eine Änderung der Lebensumstände entstehen, nicht mit in die Betrachtung einfließen. Als grobe Annäherung, die vergleichbare Visualisierung für mehrere Standorte zulässt, wurde hier ein Anteil aller Fortzüge einer Postleitzahl als Schwellenwert gesetzt (ähnlich Hölzel & Milbert, 2023). In der Umzugsstudie der Postadress (2021) erreichen Fernumzugsgründe 30 % aller Umzüge (Arbeitsplatzwechsel, Aus-/Weiterbildung sowie Trennung). Ausgehend von einer Postleitzahl werden die 70 % stärksten Fotzugsverflechtungen betrachtet (inkl. Umzüge innerhalb der Postleitzahl).

Zur Visualisierung der Analyseergebnisse werden Karten verwendet, da diese die einfachste Möglichkeit darstellen, um räumliche Verflechtungen abzubilden (Hölzel & Milbert, 2023). Gleichzeitig ist eine gesamtdeutsche Darstellung durch die Überlagerung der Wohnungsmärkte und der kleinräumigen Betrachtung nicht möglich, weshalb im Folgenden einzelne Regionen exemplarisch betrachtet werden.

Hierfür werden die folgenden zwei Entscheidungen getroffen:

(1) Um die Auswirkungen unterschiedlicher Raumstrukturen zu analysieren, werden drei Beispiele je RegioStaR7 – Region (BBSR, 2021) vorgestellt. Die Beispiele wurden zufällig, unabhängig vom Ergebnis, gewählt.

(2) Um der graduellen Natur von Wohnungsmärkten gerecht zu werden, werden die Größen der Fortzugsströme in vier Abstufungen dargestellt (gemessen an dem Anteil der Fortzüge aus der gewählten Postleitzahl).

4 UMZUGSVERFLECHTUNGEN UND WOHNUNGSMÄRKTE

Im Folgenden werden mehrere Beispiele für jede RegioStaR7-Region vorgestellt, diskutiert und mögliche Gründe für die Beschaffenheit der Fortzüge gesammelt.

4.1 Metropolen

Die drei betrachteten Immobilienmärkte liegen in den Top 7 Städten und weisen einen hohen ungedeckten Wohnungsbedarf auf (Abb. 1; BPD & Bulwiengesa, 2023). In 60594 Frankfurt sind auch die angrenzenden Gemeinden, und insbesondere die sozialstrukturell zu Sachsenhausen-Nord vergleichbaren nördlichen Gemeinden, Teil des Wohnungsmarktes – unter den Fortzügen ist die Stadtgrenze kaum zu erkennen. In 50823 Köln (hier nicht dargestellt) trifft dies, ausgehend von Ehrenfeld, größtenteils auf die linksrheinischen Gemeinden zu. Die Trennwirkung des Rheins fällt deutlich stärker als die des Mains aus. Neben der geringeren Dichte an Brücken über den Rhein als über den Main, kann auch die unterschiedliche Sozialstruktur im rechtsrheinischen Köln eine Rolle spielen.

Die Fortzüge aus der Berliner Postleitzahl 12359 (Neukölln / Britz) bündeln sich in drei Gruppen: Die erste, größte Gruppe bilden Fortzüge, die im Süden von Berlin verbleiben, aus. Die Stadtgrenze wird nur in Ausnahmefällen überschritten. Eine zweite Gruppe zieht vermehrt in den Nordwesten Berlins (primär Reinickendorf / Spandau). Als dritte Gruppe fallen vereinzelte Umzüge in den Osten Berlins nach Marzahn-

Hellersdorf und Lichtenberg auf. Mögliche Gründe sind eine ähnliche Sozialstruktur bzw. vergleichbares Mietniveau.

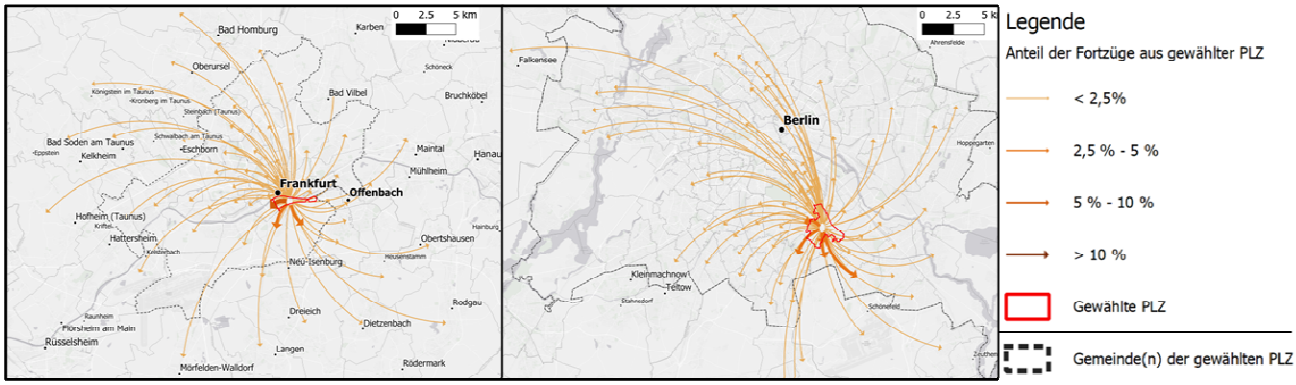

Abb. 1: Fortzüge aus den PLZ 60594 (FFM, Sachsenhausen Nord) & 12359 (Berlin, Neukölln Britz)

4.2 Regiopolen und Großstädte

Die drei Regiopolen unterscheiden sich deutlich bzgl. der Anspannung des Immobilienmarktes: In Chemnitz trifft ein geringer Wohnungsbedarf auf ein hohes Angebot, in Rostock (hier nicht dargestellt) ein mittlerer Wohnungsbedarf auf eine deutlich zu geringe Bedarfsdeckung und in Freiburg ein sehr hoher Wohnungsbedarf auf eine deutlich zu geringe Bedarfsdeckung (Abb. 2; BPD & Bulwiengesa, 2023).

Die betrachteten Fortzüge finden in 09112 Chemnitz fast vollständig innerhalb der Stadtgrenze statt. Hier könnte zusätzlich das breite Angebot von Einfamilienhäusern eine Rolle spielen (Suburbanisierung innerhalb der Stadt). Auch in 18106 Rostock finden viele Fortzüge innerhalb der Stadtgrenzen statt. 79104 Freiburg zeigt ein anderes Muster: Eine Vielzahl der Umzüge geht Richtung nahes Umland. Auch Fernumzüge sind in der Visualisierung dargestellt. Hier könnte der hohe Studierendenanteil die Ergebnisse beeinflussen.

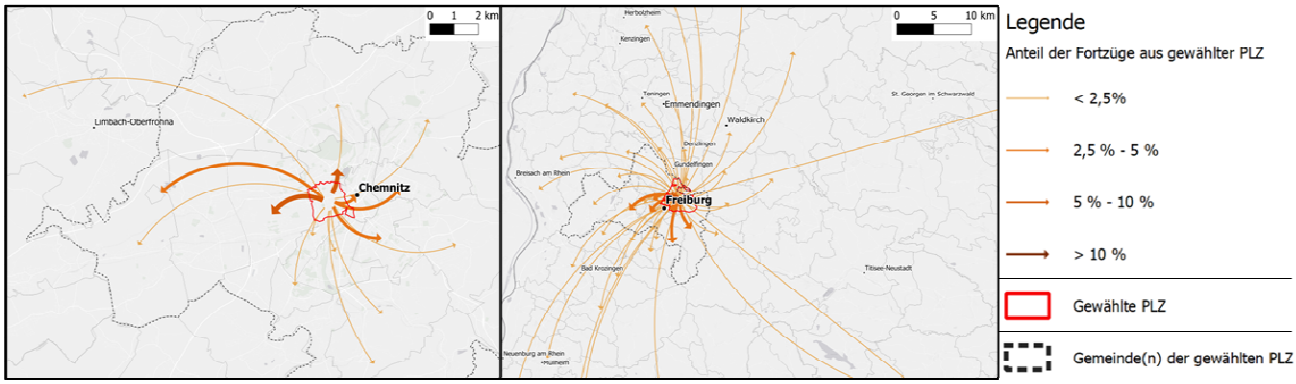

Abb. 2: Fortzüge aus den PLZ 09112 (Chemnitz, Kaßberg) & 79104 (Freiburg, Osten)

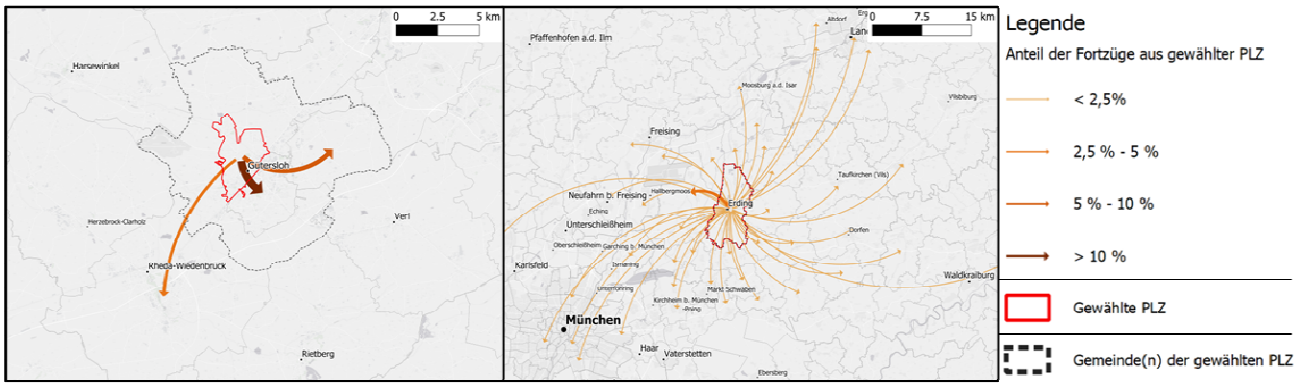

Abb. 3: Fortzüge aus den PLZ 33330 (Gütersloh, Innenstadt) & 85435 (Erding)

4.3 Mittelstädte, städtischer Raum einer Stadtregion

Die drei Mittelstädte Gütersloh, Erding und Wallenhorst (hier nicht dargestellt) zeigen sehr unterschiedliche Fortzugsdistanzen: Aus dem Gütersloher Zentrum (33330) ziehen Haushalte primär innerhalb von Gütersloh

oder in das benachbarte Rheda-Wiedenbrück um (Abb. 3). Ähnlich wie Chemnitz bietet auch Gütersloh ein breites Wohnungs- und Hausangebot. Gleichzeitig ergeben sich kaum Preisvorteile bei einem Auszug aus der Stadt in das Umland. In 49134 Wallenhorst scheint vor allem die Siedlungsdichte und das Angebot an Wohnraum die Umzugsrichtungen zu beeinflussen.

Das Umland von Erding ist dagegen dünn besiedelt. Zudem ist der regionale Wohnungsmarkt aufgrund der Nähe zur Landeshauptstadt München deutlich angespannter als in den Vergleichsstädten. Dies schlägt sich in deutlich höheren Fortzugsdistanzen nieder.

4.4 Kleinstädtischer dörflicher Raum einer Stadtregion

Das in der Nähe des Rheins gelegene Gau-Algesheim verdeutlicht die Trennwirkung von Flüssen: Alle visualisierten Fortzüge verbleiben auf der südlichen Rheinseite und damit auch im Bundesland Rheinland-Pfalz. In Rastede ziehen Haushalte primär in die Richtung der Regiopole Oldenburg. Auch die Fortzüge aus der ostdeutschen Postleitzahl 07616 (hier nicht dargestellt) sind durch die Besiedlungsdichte im Umland geprägt: Umzüge finden Richtungen Jena, Eisenberg, Stadtroda und Hermsdorf statt.

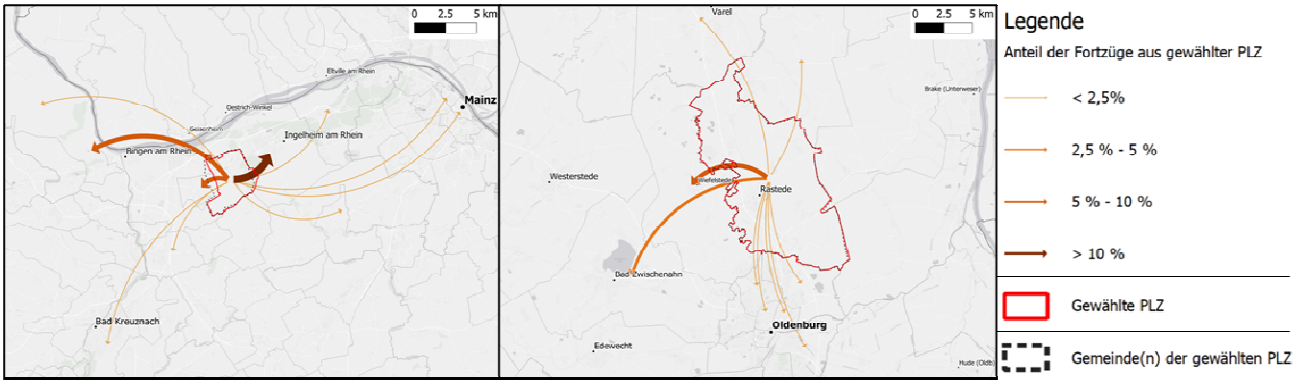

Abb. 4: Fortzüge aus den PLZ 55435 (Gau-Algesheim) & 26180 (Rastede)

4.5 Zentrale Städte einer Ländlichen Region

Celle (hier nicht dargestellt) mit rund 70.000 Einwohnern verfügt über fünf Postleitzahlen, Brandenburg an der Havel mit ebenfalls gut 70.000 Einwohnern über vier Postleitzahlen, während Coburg mit gut 40.000 Einwohnern eine Postleitzahl zugeteilt wurde. Fortzüge über die Gemeindegrenzen sind dennoch sehr gut zu vergleichen.

Unmittelbar an der südlichen und westlichen Stadtgrenze von Celle liegen mehrere kleine Ortschaften. In Coburg ist dieses Phänomen noch deutlicher ausgeprägt: Beispielsweise schließt Dörfles-Esbach unmittelbar an die Siedlungsstruktur Coburgs an. In anderen Regionen wurden ähnliche Siedlungsstrukturen im Zuge der Gemeindereformen seit Ende der 1960er Jahre zu einer Gemeinde zusammengefasst. Dementsprechend zeigen auch die Fortzugsbewegungen eine deutliche Verflechtung mit dem nahen Umland. Brandenburg an der Havel unterscheidet sich dadurch, dass die Gemeindegrenzen deutlich großzügiger gezogen sind. Gleichzeitig ist das Umland sehr dünn besiedelt, und es existieren kaum Ausweichstandorte für Fortziehende mit Lebensmittelpunkt in Brandenburg an der Havel.

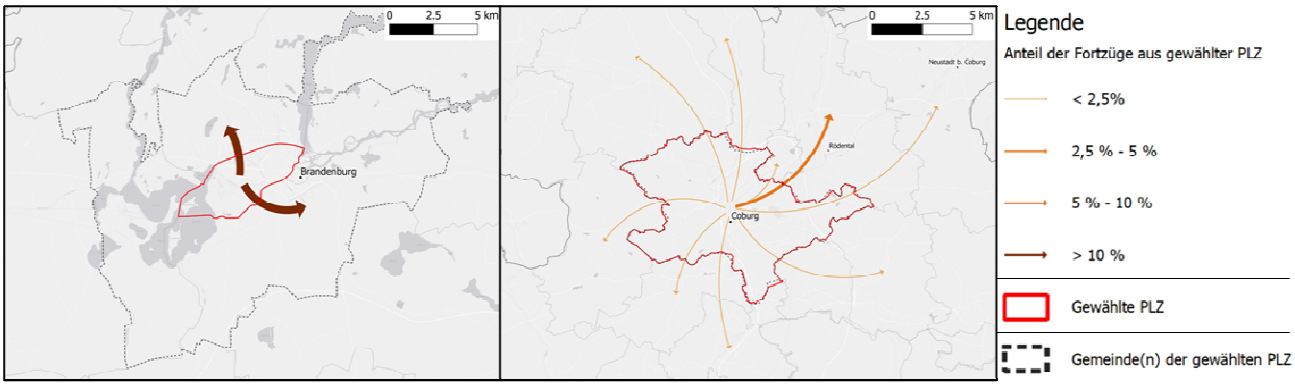

Abb. 5: Fortzüge aus den PLZ 14770 (Brandenburg a. d. Havel, Zentrum/Westen) & 96450 (Coburg)

4.6 Mittelstädte, städtischer Raum

Hann. Münden (hier nicht dargestellt) liegt zwischen den Städten Göttingen und Kassel (Abb. 6). Dennoch ist keine ausgeprägte Ausrichtung auf die beiden Großstädte festzustellen. Stattdessen existieren primär Fortzugsbewegungen in das nahe Umland. Die Fortzüge aus Bad Aibling zeigen deutlich mehr Fortzüge Richtung Osten. Zum einen ist die Bevölkerungsdichte rund um Rosenheim höher. Zum anderen ist der Immobilienmarkt Richtung München deutlich angespannter. Auch in Biberach zeigen sich Umzugsbewegungen Richtung Wohnungsangebot (Mittelbiberach und Warthausen).

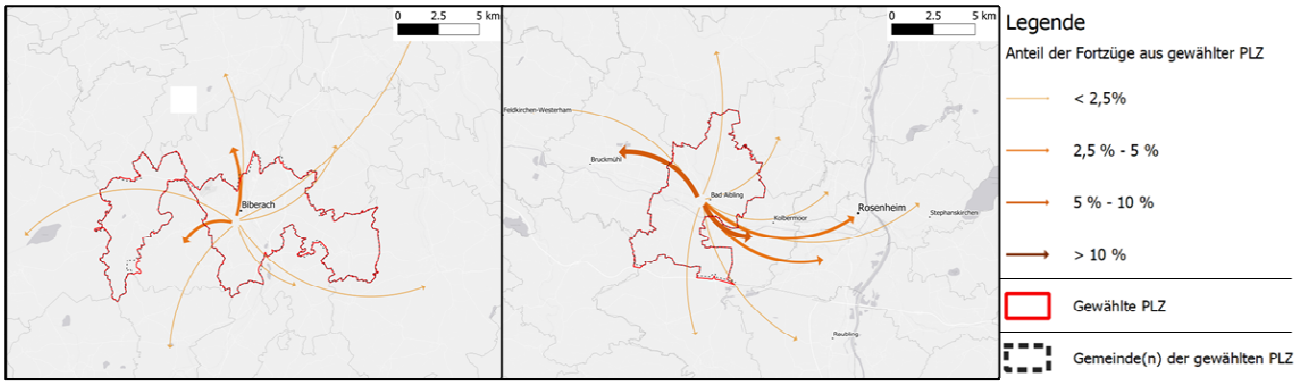

Abb. 6: Fortzüge aus den PLZ 88400 (Biberach an der Riß) & 83043 (Bad Aibling)

4.7 Kleinstädtischer, dörflicher Raum einer ländlichen Region

Die Postleitzahl 18569 auf Rügen ist kein alleiniger Tourismusstandort (Abb. 7). Im Vergleich zu direkten Ostseelagen ist der Immobilienmarkt deutlich entspannter. Dementsprechend finden auch Fortzüge nicht Richtung Ostsee, sondern in die Postleitzahlen im Hinterland Rügens statt.

Die Postleitzahl 59969 (hier nicht dargestellt) umfasst eine Gemeinde aus Hessen (Bromskirchen) und eine Gemeinde aus NRW (Hallenberg). Diese Betrachtungsebene lässt keine Rückschlüsse zu, ob die Bundeslandgrenzen auch Umzugsgrenzen darstellen.

Arnstorf in Niederbayern liegt in einer der am dünnsten besiedelten Regionen Deutschlands. Weiter entfernte Fortzüge entfallen vor allem auf die für die Region größeren Gemeinden.

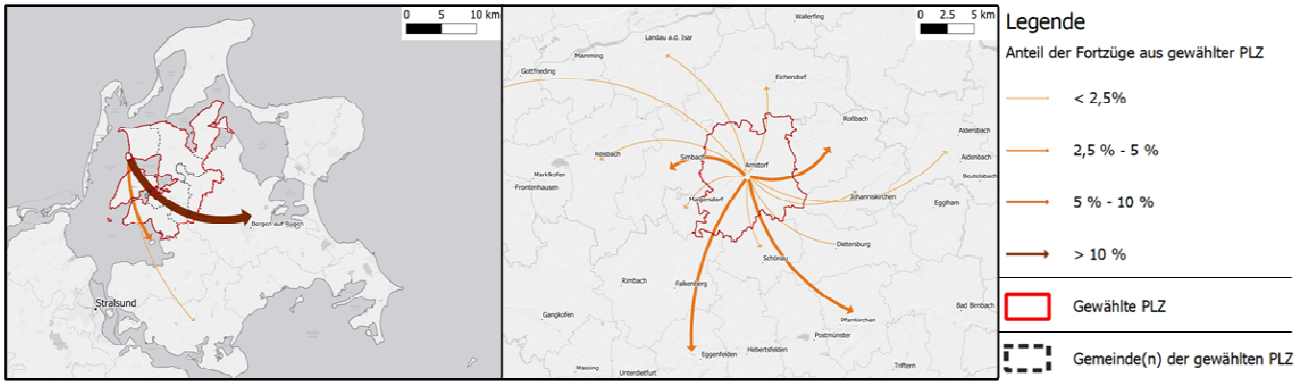

Abb. 7: Fortzüge aus den PLZ 18569 (Schaprode, Trent, Neuenkirchen, …) & 94424 (Arnstorf)

5 SYNTHESE

Aus den betrachteten Visualisierungen lassen sich mögliche Einflussfaktoren auf die Bildung räumlicher Wohnungsmärkte bündeln. Da es sich hier um eine exemplarische Betrachtung ausgewählter Standorte handelt, können keine allgemeinen Rückschlüsse getroffen werden. Die Gruppierungen sind als Hypothesen zu sehen und erfordern weitere Untersuchungen. Gleichzeitig sind die Einflussfaktoren immer multidimensional. Beispielsweise ist in diesem Beitrag nicht zu klären, in wie weit die Siedlungsstruktur oder die Anspannung des Immobilienmarktes ausschlaggebend für die Bildung eines Wohnungsmarktes ist.

Der auffälligste Faktor, der einen Einfluss auf die Distanz und Richtung der Fortzüge zu haben scheint, ist die Anspannung des Immobilienmarktes. Besonders in den Regiopolen (Chemnitz vs. Freiburg) und Mittelstädten (Gütersloh vs. Erding) wird dieser Unterschied deutlich. Die Fortzugsdistanzen liegen in den

angespannteren Wohnungsmärkten (Freiburg und Erding) deutlich höher. Die Fortzüge verteilen sich auf deutlich mehr Postleitzahlen.

Hypothese: **Je angespannter ein Wohnungsmarkt, desto höhere Umzugsdistanzen.**

An mehreren Standorten zeigt sich zudem die Wirkung natürlicher Barrieren. Besonders auffällig ist die Barriere Rhein im Beispiel Gau-Algesheim. Ein weiterer Einflussfaktor könnte an dieser Stelle auch der Bundeslandwechsel darstellen. In Rügen ist die Barriere des Meers deutlich zu erkennen. Trotz vorhandenen Wohnraums auf dem Festland verbleiben alle visualisierten Fortzüge auf der Insel. Gleichzeitig ist nicht jeder Fluss automatisch eine Barriere: In Köln fällt der Effekt geringer aus, und in Frankfurt am Main sowie Rostock ist keine Trennwirkung feststellbar.

Hypothese: **Natürliche Barrieren formen die Fortzugsrichtungen.**

In den Fällen Wallenhorst und Rastede könnte schlichtweg die höhere Bevölkerungsdichte (und das damit verfügbare Wohnungsangebot) in Osnabrück und Oldenburg eine höhere Fortzugsdichte in diese Städte hervorrufen. An Coburg grenzen unmittelbar Suburbanisierungsstandorte, die nur durch administrative Grenzen von der Stadt getrennt sind. Das Gegenteil zeigt Brandenburg an der Havel: Hier existiert kein dicht besiedeltes Umland. Dementsprechend verbleiben alle visualisierten Umzüge in der Gemeinde.

Hypothese: **Die Bevölkerungsdichte / das Wohnungsangebot bestimmt die Fortzugsrichtungen.**

Abschließend ist die Wirkung der Sozialstruktur ist nur in Kombination mit anderen Einflussfaktoren erkennbar. Am deutlichsten erscheint dieser Einflussfaktor in Berlin. Gleichzeitig könnte auch hier nicht die Sozialstruktur, sondern die Anspannung des Immobilienmarktes der maßgebliche Einflussfaktor für die Fortzugsrichtungen darstellen. Die Hypothese erscheint damit die unsicherste.

Hypothese: **Haushalte wählen sozialstrukturell ähnliche Wohnstandorte (zu ihrem aktuellen Standort).**

6 FAZIT

Die kleinräumige Betrachtung von Fortzügen hat deutliche regionale Unterschiede bezüglich der Beschaffenheit von Wohnungsmärkten aufgezeigt. Die Umzugsdistanzen und -richtungen scheinen in deutschen Wohnungsmärkten durch die Anspannung des Immobilienmarktes, durch die Existenz von natürlichen Barrieren, durch das Angebot am Wohnungsmarkt sowie das sozialstrukturelle Umfeld beeinflusst zu werden. Der größte Unterschied dieses Beitrags zur bestehenden Literatur ist die kleinräumige Betrachtungsebene, die auch die Analyse von einzelnen Stadtteilen und Wohnungsmärkten am Rande von anderen administrativen Grenzen erlaubt.

In der Praxis kann die Analyse Wohnungsunternehmen und Planern helfen, das Umzugsverhalten von Haushalten besser nachzuvollziehen. Anhand der entwickelten Hypothesen kann ein allgemeines Verständnis entstehen, wie sich ein Wohnungsmarkt unter typischen Rahmenbedingungen bildet. Die Ebene der Postleitzahl hat sich dabei als eine sinnvolle Auswertungsebene erwiesen. Unterschiedliche Größenzuschnitte im städtischen und ländlichen Raum machen deutschlandweite Analysen ohne Fallzahlprobleme bei einer gleichzeitig kleinräumigen Betrachtungsebene möglich.

Die hier gewählte Schwellenwert-Methodik kann Fernwanderungen nicht vollständig ausschließen. Die Visualisierung in Freiburg zeigt beispielsweise Fernumzüge, die vermutlich durch Arbeitswanderungen von Studierenden zu begründen sind. Eine Entwicklung von Methoden, die den Ausschluss von Fernumzügen optimieren, sollte im Fokus zukünftiger Forschung stehen.

Die Visualisierung von Umzügen erlaubt zudem nicht, unterschiedliche Einflussfaktoren untereinander zu gewichten oder eindeutig zuzuordnen. Die statistische Signifikanz und Relevanz der entwickelten Hypothesen kann hier nicht bestätigt werden. Auch an dieser Stelle sollten sich zukünftige Arbeit zum Ziel setzen, die Hypothesen durch geeignete Forschungsdesigns zu testen.

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Smart Urban Resilience: From Nature-Based Solutions (NBS) to Nature-Positive Cities and Landscapes

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1 ABSTRACT

In the current context of intensified climate change, global society is facing severe challenges. Among the various dynamics having a strong environmental and socio-economic impact on our lives, the increase in urbanisation demands particular regard. According to statistics published last year by the World Economic Forum, it is predicted that by 2050, nearly 70% of the world's population will live in cities (WEF, 2023), thus aggravating urbanisation's highly disruptive effects on the environment. Hence, creating smart and resilient cities emerges as an urgent and indispensable priority if both human and environmental well-being are to be safeguarded. nature-based solutions play a crucial role in improving urban mobility, climate resilience and resource efficiency, provided they leverage cross-cutting cooperation and engage local communities. Consistent efforts towards nature-positive cities have been made by the international landscape consultancy LAND for over 30 years, in particular through actions aimed at depaving urban soils ("Let's Break it Up!") in Northern Italian metropolitan areas, through large scale territorial and sociocultural transformation in the wider Essen area in Germany, through the development and application of digital Natural Capital Accounting tools within the European project UrbAlytics and through innovative landscape planning in Saudi Arabia.

Keywords: landscape, nature, urban, city, resilience

2 NATURE-BASED SOLUTIONS AT THE TIME OF CLIMATE CRISIS

Nature-based solutions (NBS) are technical approaches capable of providing multiple benefits by supporting, restoring, and enhancing urban nature. The terms generally refer to "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, providing human well-being and biodiversity benefits." (Cohen et al. 2016). From species diversity conservation to air quality improvement, or mental health enhancement, the effectiveness of nature-based solutions depends on the local context in which they are implemented: their design requires an approach based on knowledge of the landscape components of the involved area, considering environmental and climatic conditions as well as social and cultural factors. Furthermore, the European Commission defines nature-based solutions as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions" (EU, 2022). As such, NBS are an essential step towards Nature-Positive Cities (NPC), i.e. cities which developed an action plan according the AR^{3}T framework[1], while committing to well-defined science-based targets (WEF, 2024). The NPC mission aims at building more resilient, prosperous, and equitable cities by 2030 through three core pillars: inspire nature-positive urban development by empowering urban leaders and enablers through new policy models, regulations and incentives; foster dynamic public-private collaboration; and drive a scalable impact by deploying nature-based solutions in pilot cities through the integration of nature in the built environment. Landscape projects thus play a central role in creating places that are resilient to climate

[1] The AR^{3}T framework sets goals as follows:
AVOID: Protect areas and land use; prevent water pollution, facilitate the transition to green energy sources;
REDUCE: mitigate city development impact, reduce water consumption and utilize renewable water, reduce waste and improve energy efficiency;
RESTORE&REGENERATE: rehabilitate land wetlands and shorelines, reverse desertification, ensure water quality standards, promote sustainable forestry and agricultural practices;
TRANSFORM: integrate nature into urban planning and policies ensure sustainable water management policies, adopt circular economy.

change, attractive, accessible, and safe, provided they directly involve public administrations, professionals, stakeholders and citizens.

2.1 Landscape projects to shape the city of the future

The international landscape consultancy LAND, founded in 1990, has committed to focus its research on NBS, offering solutions to make cities more liveable and resilient. Among them, the adoption of blue-green infrastructures has proved to be an effective strategy to address complex environmental challenges in urban contexts, systematically combining green areas and vegetation with water elements and drainage solutions (EC, 2013, 249). In this regard, depaving is a fundamental undertaking, intended as the targeted process of removing impermeable surfaces in urban areas to restore natural soil and enable the healthy growth of plants (EC, 2021). The de-impermeabilization of soil facilitates the return to its capacity to absorb and retain water, a crucial aspect, especially considering the increasing frequency of extreme weather events such as intense precipitation concentrated in short periods. Moreover, this innovative practice reduces the presence of surfaces that absorb and radiate heat. Allowing the introduction of vegetation, it makes open spaces more comfortable thermally, thanks to the shading and evapotranspiration properties of plants.

Launching a key initiative under the targeted message "Let's Break It Up!" has effectively helped to reintegrate nature into the metropolitan areas of Milan, Turin, Vercelli and Essen by depaving streets, introducing permeable surfaces, and strategically planting trees to improve microclimates and overall urban liveability. The project gives rise to a new season of radical interventions in cities, where nature gains ample space to thrive and provide the environmental, social, and economic benefits needed to ensure more liveable cities for the new generations. Breaking the asphalt to let water flow openly again and allowing plants to take root in fertile and vital soil also aims to reconnect people with nature. As part of the Nature-Positive Cities initiative, the project further aims to support public and private sectors coalesce around common principles to recalibrate cities relationship with nature by promoting coordinated tangible actions and fostering a profound shift in urban development based on harmony between cities and environment.

3 FROM NATURE-POSITIVE CITIES TO NATURE-POSITIVE LANDSCAPES

For cities of the future to prosper and thrive, urban programmes should thus foster nature as a pillar of regeneration plans, considering the connections between urban fabric and the countryside, in a shift towards nature-positive landscape. The environmental crisis underway has led us to understand that the landscape in which we live is a complex and highly interconnected system. Landscape doesn’t begin at the edge of cities, but in the city, in every home. It’s a matter of being “in between” spaces and spatial dimensions (Kipar, 2023). Therefore, it is necessary to seek comprehensive and radical solutions to consider the interactions of natural systems that are completely interdependent with social systems. It is fundamental that cities undertake a comprehensive assessment of their local context, considering the specific environmental challenges, biodiversity hotspots, and community needs in the development of every plan and strategy. Recognizing the uniqueness of each city's ecological, social, and economic landscape is paramount in the development of a successful action plan, that should take into account the connections and interdependencies between city and country, city and landscape.

Urban nature, when strategically planned, can originate an osmotic system, which is permeable and implementable through multiple and collaborative processes with citizens, municipalities, and institutions. This approach to landscape design actively promotes the implementation of concrete, radical, and ecological behavioural processes through the construction and development of green spaces. Nevertheless, those processes are demanding urgent change, spanning from environmental to social and economic dimensions. Aiming to move from a vision of nature-positive cities (where the artificial and total built dimensions are the main focus) to a more radical one placing landscape and its positive impacts on the natural and human dimensions at the centre of the professional and scientific discussion, this new analysis and action frame is crucial for landscape designers and planners.

3.1 Approaching Nature-Positive Landscapes: the case study of Essen

With the Internationale Bauausstellung Emscher Park (IBA, 2000) in Essen, which lasted from 1989 to 1999, landscape architecture started playing an essential role in mediating between economic, social, and political interests in the Ruhr, summoning local communities. A deep structural change was initiated, transforming

one of the largest metropolitan areas in Europe into a greener, more liveable and increasingly nature-positive region. Spanning on an area 800 km2 wide, involving 17 cities and 2.500.000 residents within 150 projects, the park worked as catalyst connecting fragmented landscape areas. The regeneration from grey to green infrastructures gave a new identity to the entire industrial region, creating a fluid landscape where settlement development was finally based on an ecological footprint, thanks to an unprecedented cell-like spatial structure. To recover and expand the natural capital of the Ruhr, the master plan "Freiraum schafft Stadtraum" (Open Space Creates Urban Space, 2005) created a network of green infrastructure between former industrial areas in the north of Essen and the city centre, amplifying the vision of previous master plans "Emscher Zukunft" and "Emscher Landschaftsparrk". It followed a three-step collaborative and participative approach: opening new perspectives (Belichten) to define open areas, connecting these new areas with their surroundings through installations and events (Inszenieren), and eventually rooting the areas in the city through targeted projects (Projektieren). In addition, the master plan was integrated by the public-private project "Essen. Neue Wege zum Wasser" (2006), drawing inspiration from Milan's Green Rays Model. To define the core areas of action towards a structural nature-positive revolution, thematic rays were identified along the existing waterways of the city. The roughly 230 hectares hosting the Kruppsche cast steel plant, which had been inaccessible to the public for over 200 years, were reunited with the city forming a unique green belt. By filling this urban void between the Altendorf district and the centre of Essen, Krupp Park opened in 2009 and combined the ecological needs of the area, such as drainage from the ThyssenKrupp Headquarters, with the features of a green public space dedicated to citizens' well-being and relaxation. The project engaged schools, universities, associations and businesses to participate, while the overall green network positively affected mobility, local economy and quality of life. Moving 400,000 m³ of land, the "Five Hills" park was shaped, embracing a 9,000 m² lake and a regional bike path, on the route of the disused "Rhine Railway." Through this osmotic network of green and blue infrastructure, which helped to account for the natural capital of the region, Essen became "culture capital of Europe" in 2010 and "green capital of Europe" in 2017. Through the "green decade", it has set its sights on the international Gartenbauausstellung IGA 2027 and beyond, with future goals already in place. These achievements have established Essen as an international role model, highlighting the city's responsibility in promoting change.

4 DIGITAL LANDSCAPE: TOOLS AND METHODS FOR MEASURING NATURE

Data modelling and reporting on the quantitative and qualitative values of nature in the city are essential steps for the design and supply of NBS in complex and heterogeneous environments; moreover, they are actions needed to turn cities and landscapes nature-positive.

The core mission of "Reconnecting people with nature" has found a promising application in the digital dimension through new forms of landscape perception, fruition and promotion: digital technology allows expanding, connecting and monitoring landscape, quantifying natural capital in terms of extension, state of health and benefits provided by ecosystems. The great potential of Digital Landscape (Balestrini, 2020) lies in re-establishing the human scale in our cities through an intelligent and interactive way following the needs of communities and the vocations of their territories, stimulating an act of conscious care of their natural and cultural capital. Natural Capital Accounting (UN, 2020) makes it possible to quantify every project's performance based on environmental parameters related to greenery and water management, climate change mitigation and air quality provided by LIM® database[2], with the objective of enhancing liveability conditions in cities.[3]

[2] LIM® (landscape information modelling) helps quantify landscape ecosystem services: it's a data-based process that assesses positive environmental impacts produced by vegetation, providing specific predictions for all tree species (carbon sequestration, reduction of ozone concentration, oxygen production).

[3] "Natural capital is another term for the stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people." The concept of natural capital extends beyond nature as a source of raw materials for production to include the role of the environment and ecosystems in supporting human well-being through the supply of such important goods and services as clean water, fertile soils and valuable genetic resources. Since the early 1970s, interest in the practical applications of a natural capital perspective has grown considerably within government, business, civil society and academic communities." (UN, 2017).

4.1 Fighting the urban heat island effect: the UrbAlytics project

In the era of climate emergency, landscape design must also be ethically justified. Integrating research units into private companies helps to inform concrete projects and planning with innovative and future-oriented technical solutions, as is the case with LAND's Research Lab®.[4] In compliance with UN Agenda SDGs and the New European Bauhaus principles (inclusivity, aesthetics, sustainability), the Research Lab® has developed a Sustainability Compass showing how given projects integrate these guidelines. This tool has found its best practice in the UrbAlytics project, an experimental sub-project of the H2020-funded project AI4Copernicus that combines artificial intelligence with Earth satellite observation producing information layers that can support city planners and decision-makers in the context of climate resilience and related challenges in urban areas. This research investigates, thanks to the joint expertise of the partners Latitudo 40 and LAND Research Lab®, the Urban Heat Island (UHI) effect evaluating its impacts on cities, assessing Ecosystem Services provided by Blue and Green Infrastructures and proposing a set of nature-based solutions (NBS) for climate adaptation and extreme heat mitigation. The methodology built up during the project proved to be fundamental in demonstrating how technology can be useful to measure impacts and benefits of nature in the city.

The preparatory research to identify new ways of mapping digital landscapes for nature-positive cities, i.e. research for the management and planning of green solutions according to new technologies also increases competitiveness in the international arena. A continuous development and implementation of the Research Lab® activities enable the enrichment of design challenges with new themes and lines of development, resulting in a demand for refined consultancy services with respect to European sustainability principles and protocols. The models and technological tools we develop reflect the mission to build knowledge based on nature-positive landscapes across the scales. Moreover, the research unit promotes and manages complex landscape transformation processes through solutions that respond to the most pressing challenges of our society. The commitment of the Research Lab® in the international sphere has made it possible to implement the spin-offs of consultancy services and research actions for applying to European Horizon calls with qualified international consortia.

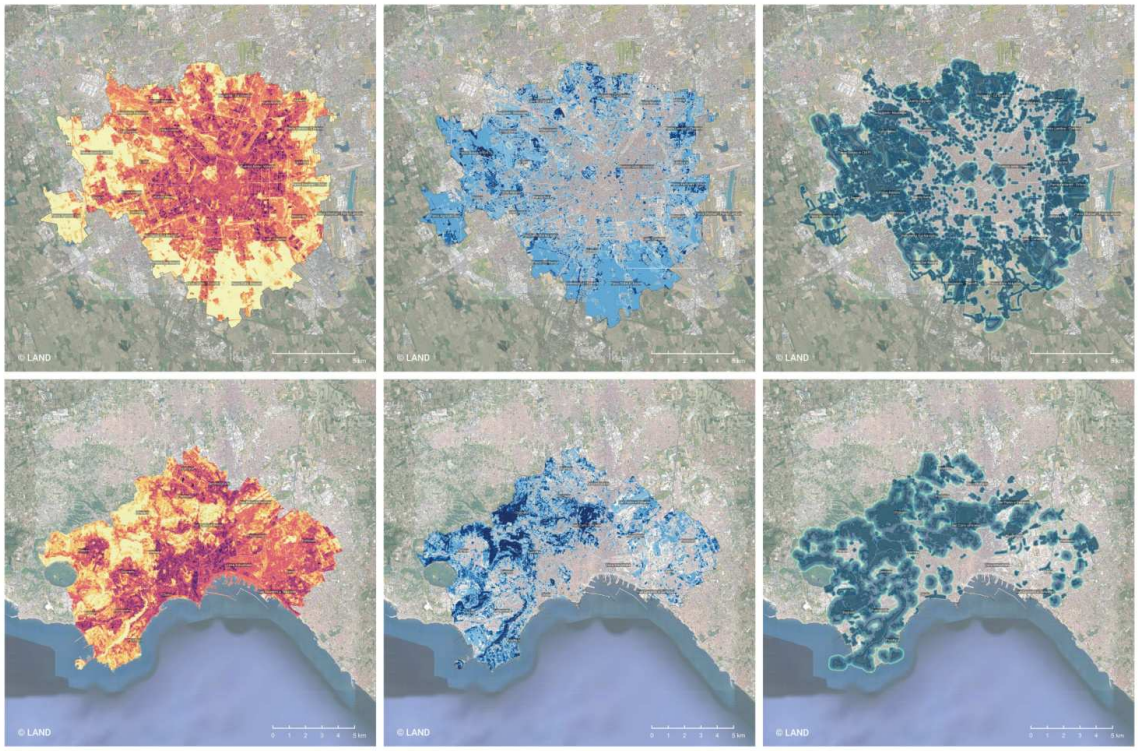

Fig. 1: Heatwave Potential Risk (HPR) Index, Microclimatic Performance Index (MPI) of urban vegetation and Park Cool Islands (PCI) Assessment in Milan and Naples, Italy. Data produced by LAND and Latitudo40 in the UrbAlytics project, 4th Open Call of AI4Copernicus (Horizon 2020). Sentinel 2 database, UHI risk analysis considering Land Surface Temperature data during summer months from 2018 to 2022.

[4] LAND Research Lab® is committed to foster research by delving into five fields of landscape applications: streetscape, water-sensitive design, urban forestation, slow mobility, digital landscape and public space.

5 A STRONGER COMMITMENT FOR PUBLIC WELL-BEING

An increasing "call for Nature" is spreading across the continent: according to the latest statistics of the European Commission survey (EU, 2023), climate change remains among the top three concerns of Europeans and an overwhelming majority support action across the Union to tackle the climate crisis and make Europe the first climate-neutral continent. Unprecedented intervention could also improve public health, as furtherly underscored by the European Biodiversity Strategy for 2030 (EU, 2020aiming at the recovery of species for the benefit of people, climate and the whole planet. The essence of human well-being is thus intricately tied to the natural world and serves as the cornerstone for every economic endeavour. Collaborative and coordinated efforts are essential to address the dynamic relationship between the environment and climate. With respect to natural ecosystems, our shared responsibility involves stabilizing the climate, safeguarding freshwater reservoirs, rejuvenating landscapes, ensuring the vitality of oceans, and conserving biodiversity. It is imperative to undertake these endeavours within scientifically established boundaries and with a commitment to social equity, in the hope that this radical shift of paradigm can radiate to other continents.

5.1 Improving the citizens' quality of life in Saudi Arabia

In 2016, the Kingdom of Saudi Arabia entered a new historical phase launching Saudi Vision 2030 (Saudi Arabia, 2023), a strategic program aimed at improving government efficiency, stimulating growth and investment opportunities, and most importantly, enhancing visitors and residents' wellbeing. The mission of creating an ambitious Nation entails the opportunity of enabling social responsibility thanks to a specific Quality of Life program, bound to promote happiness and fulfilment for all Saudi citizens. The Royal Commission for Riyadh City launched the Green Riyadh Program (Riyadh, 2023) to further fuel these objectives through, above others, the development of city parks. The program aims to strategically increase the quality and quantity of all vegetation in both urban and suburban setting and develop a strategically planned interconnected network of natural and semi-natural areas with other environmental features, designed to deliver a wide range of ecosystem services. To achieve the above, the Strategy targets to increase vegetation coverage in Riyadh from the current 1.5% to 9.1% in 2030. Green Riyadh initiatives span over 541 km2 of Green Space and along a Green Belt of 1.100 km2.

Complying with the Saudi Vision 2030 is Al Urubah Park – a 75-ha park where a piece of nature is secluded by a 3 km long building – the first City Park within the Green Riyadh Program. The park brings organic and fluid elements to the city. It nurtures a dialogue with the wadis and the surrounding areas: the west side of Al-Urubah is characterized by a natural system consisting of Wadi Hanifa, Wadi Al-Laysan and sand dunes, edging the city by a winding strip of farms, parks and green plot. Within the Nature-positive landscape perspective, the project got integrated into the existing context by reproducing a "piece of nature" inside the urban fabric: the interpretation of the territorial elements converged at the site through the planting of over 10.000 trees, the use of existing soil for inner paths and the utilization of Riyadh stone and granite transformed in contemporary urban furniture. Shadow represents the connecting feature for all public spaces to ensure a liveable outdoor space for all Riyadh citizens. The park also serves as retention pond in case of extreme rainy events, pursuing the Green Riyadh Program goal to safeguard the Kingdom's environment and promote the optimal use of water resources by reducing consumption and utilizing treated and renewable water. Moreover, the innovative Digital Landscape monitors the park's environmental data, provides cultural in-depth tools with specific points of interest, and intends to become the digital control core for all the parks yet to be developed within the initiative. Working on connectivity, regeneration and connection of green spaces as a benchmark for future projects, the park embodies the Saudi Vision's focus on the Kingdom community by enhancing the participation and experience of "a vibrant society…with fulfilling lives".

6 CONCLUSION

Nature-based solutions have emerged as essential for infusing a green essence into global cities and mitigating climate change. This holds especially if we recognise that nature is already in the city, rather than considering it as an abstract dimension in antithesis with the urban realm. In accordance with this recognition, natural capital is in fact the result of what has been understood as the natural and geographical vocation of cities.

In this respect, the integration of Natural Capital Accounting can enable the quantification and replication of sustainability in landscape projects on a broader scale.

To acknowledge nature as an asset, incorporating natural capital management into urban planning should be prioritized. This contributes to create Nature-positive cities which balance urban development with environmental conservation, promoting the well-being of both residents and the planet. Only by disseminating Nature-positive cities around the world will we be able to see the concrete benefits of an improved enabling environment. Among these benefits, we count enhanced processes and transparency in city governances, improved climate risk management frameworks to reduce accidents and unexpected events, increased investment from MDBs and ESG-aligned investors, an enhanced spirit of innovation, the replication of governance and communication mechanisms across society and the cultivation of talent and culture. Such innovative solutions offer a holistic approach to urban planning that addresses multiple challenges while fostering more and more sustainable, resilient, and liveable environments: nature-positive landscapes. Thus, to enable the green transition to Nature-positive cities we need to start from designing the big picture of change. How? Starting from landscape, with three basic guidelines for leading design practices: making landscape visible, making it measurable with day-by-day monitoring actions and making it inclusive with people-oriented spaces and practices.

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Sustainable Concrete-Based Structures: Review for the Potential Benefits of Basalt Fiber Reinforced Concrete (BFRC) in Enhancing the Environmental Performance of Buildings

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1 ABSTRACT

Incorporating Basalt Fibers composites that are caused by the melting process of basalt rocks into the concrete mixture to create the composite of the Basalt Fiber Reinforced Concrete (BFRC) is a good idea to enhance concrete's mechanical properties, thus the concrete structural performance. However, modern building materials must fulfill not only structural performance criteria but also reduce the environmental impact accompanied by their production. As informed by related literature in the field of BFRC, benefits linked with mechanical properties in terms of structural performance were illustrated widely. While there is only a very limited amount of information available on the impact of using BFRC in terms of environmental impact. Thus, this review identified this research gap and drew a potential linkage for how to assess the environmental performance of BFRC-based buildings to be used in future research which relies on sustainability perspectives.

Keywords: Fiber Reinforced Concrete Composites (FRCC), Basalt Fiber Reinforced Concrete (BFRC), Environmental performance, Sustainable architecture, Building Planning

2 INTRODUCTION

Concrete is one of the most used construction materials in the present day due to its advantages of versatility, and generally highly reliable performance of this material, and also the widespread availability and comparatively low cost of the necessary raw materials and processing technology [1, 2, 3, 4]. Concrete-based materials are usually affected and affect the construction process negatively due to their brittle nature [5]. Many recent studies focused on these deficiencies, so that, the use of different materials as reinforcement so as to improve the properties of the hardened concrete was necessary [6, 7, 8, 9, 10, 11, 12]. These studies and other similar studies were focusing mainly on enhancing the structural aspect of the building through different approaches. One such approach to enhancing the constructional materials is the incorporation of short-length fibers at minimal dosage to develop what is termed fiber-reinforced concrete composites (FRCC) which were directly aimed at increasing positively the concrete structural properties [6, 12, 13, 14, 15, 16]. One of well reputed of these fiber composites due to its countless enhanced concrete structural benefits is Basalt Fiber Reinforced Concrete (BFRC) [17, 18, 19].

In terms of the environmental aspect, the concrete-based materials industry is facing increased pressure as concrete production is being perceived as unsustainable material. Although the energy intensity per functional unit remains lower than most other available constructional materials [20], the very large production volumes required to serve global needs for concrete lead to high worldwide consumption of energy, as well as raising in the emission of greenhouse gases (GHGs). Thus, there is a growing global interest within the housing and construction industry in the development of sustainable construction and building materials that have a diminished environmental impact throughout their manufacturing and operational lifecycle stages [4]. Thus, the development of sustainable constructional materials with reduced environmental footprint through both manufacturing and operational phases is currently a key focus in the sustainable construction industry. Furthermore, this key solution of creating sustainable construction materials is shown as essential demand.

When considering the approach of utilizing fiber composites to reinforce the concrete, a clear gap is being unfolded in terms of studying the enhancement of FRCC's environmental properties. Which can play a significant role in confronting the sustainability challenges that are linked with the worldwide large production of concrete. Specifically using the BFRC in enhancing the environmental properties of concrete constructional material. This paper attempts to discuss the concept of BFRC in terms of the literature gap of

the enhanced environmental concrete properties as a potential solution to the global issue of the resulting sustainability challenges of concrete high production as well as the energy consumption rates within concrete-based structures. As a basis for this, the current status of BFRC's approach to enhancing concrete properties is reviewed. This review highlights some of the issues in the specific context of BFRC production and outlines the importance of developing a deeper and more comprehensive understanding of thermal parameters as part of the process of broadening the uptake of this approach for creating sustainable architectural structures.

3 SUSTAINABILITY AND CONCRETE INDUSTRY

In response to the increasing pressures faced by the environment and limited resources, the term "sustainability" has been created, which includes how natural systems function, and give whatever is needed to keep the environment in balance now and in the future [21]. There are two definitions of sustainability that were considered comprehensive. The first type reflects the social scientific definitions that are summarized in treating sustainability as a relationship between the present and future welfare of persons [22, 23]. Furthermore, in the [24], the definition of sustainability is considered as it is the development that meets the needs of the present people without affecting negatively the ability of future generations to meet their own needs. This type of definition imposes ambiguity about how to make a balance between generations' welfare, which led to the emergence of the second type of definition of sustainability; the ecological definition that requires the protection of ecological processes as a condition of sustainability [25,26]. Also, again, this type of sustainability definition presents some vague related to the way in which we can protect the ecological processes. Indeed, in scientific contextualisms, sustainability should not follow any of these types on its own, instead, it should be combined. This review is trying to answer the question raised here which is (What strategy we should adopt to protect the ecological process while maintaining human welfare throughout the human development stages?) through linking sustainability with the concrete industry in the field of sustainable architecture. For more illustration about this review strategy note fig.1 below.

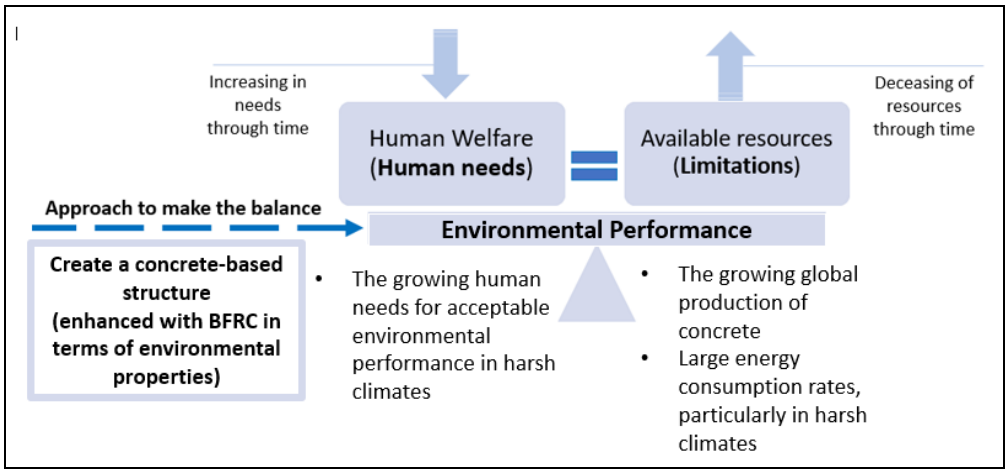

Fig. 1. The Review Paper Strategy. (Al-Bqour. N, 2023).

The key components of concrete include cement, aggregates (such as sand and gravel), and water, with additional materials like admixtures and fibers being optionally incorporated for specific purposes [27]. The total volume of cement production worldwide in 2022 amounted to 4.1 billion tons. The total global production of cement in 1955 reached 1.39 billion tons, which indicates the large growth of cement-based construction. With production surpassing two billion metric tons, China was recently the leading cement-producing country in 2022, with production surpassing two billion metric tons. Also, India ranked a distant second that year, producing 370 million metric tons [28]. A potential future shortage of low-cost raw materials is the first key point that should be considered in the context of the cement and concrete industry, regarding its huge consumption of conventional limestone-based materials [6]. The manufacturing process of cement involves the production of clinkers, which is a key component. Limestone plays a significant role in clinker manufacturing as it is used as a raw material and can also be used as a clinker replacement or additive [29]. Limestone is a widely available material, potential shortages could arise if there is an imbalance between demand and supply, particularly in regions with high cement production. The sustainability of limestone extraction forms an important consideration to ensure the long-term availability of this resource

for the next generations [30]. It is crucial for the concrete and cement industry to continually explore sustainable alternatives, such as alternative and high-performance raw materials, to reduce the reliance on limestone, and thus to mitigate any potential shortage concerns. In terms of Cement industry emissions and energy consumption, the production process of cement requires the heating of a mixture of minerals to temperatures of more than 1400 degrees Celsius in a kiln. This heating step requires energy in large amounts as an essential demand, which ends up in worldwide greenhouse gas emissions. Which could be a real threat to human welfare in harsh climates. Carbon dioxide emissions from cement production have increased nearly continuously for several decades, reaching 1.7 billion metric tons in 2021 [28]. It should be highlighted that the total emissions of the cement and concrete industry, as a whole sector, may contribute nearly 10% of global anthropogenic CO2 emissions [6]. It is quite clear now that the process of cement and concrete production has large negative effects on the environment in terms of consumption of limited resources, energy consumption, as well as air emissions that contribute to global warming, therefore, negatively impacting human welfare.

In addition to the environmental impacts discussed during the manufacturing process previously, the environmental impacts generated during the operation of the concrete-based building are equally important or even higher. This is because the embodied energy of construction materials during the manufacturing stage is only a small fraction of the total energy consumption of a building during its whole lifespan [6]. Generally, environmental assessments of buildings have tended to concentrate on the impacts occurring in operation and use. It should be noted that the environmental impacts through the building operational stage occur throughout the whole lifetime of the building, which indicates how important is to consider those long-term impacts [31]. The environmental impacts over the complete life cycle of the buildings are determined using the indicators of air pollution index, energy consumption, global warming potential, resource use, solid waste emissions, and water pollution index [32]. Considering the sustainability of buildings mainly focuses on the energy demand and emissions during the building use phase [33]. In terms of concrete-based buildings, related studies revealed that concrete-based buildings showed higher negative environmental impacts [34, 35, 36]. Also, it should be noted that concrete-based buildings have higher environmental and structural negative impacts within harsh climates [37, 38, 39, 40].

Overall, in the next decades, cement and concrete production is expected to continue to show increased growth. Demand for cement in industrialized is increasing slowly if at all, but in developing countries and regions such as India, other developing parts of Asia, the Middle East, South America, and Africa which are linked usually with harsh climates, cement demand will continually increase due to fast urbanization and associated infrastructure development [41]. Therefore, the environmental issues associated with limitations on natural resources, CO2 emission, high energy consumption, and environmental performance within concrete-based structures will play a leading and directing role in the sustainable development of the concrete industry in the coming century. Unsurprisingly, the cement and concrete industry has been fully aware of the discussed environmental challenges and has keenly focused on many positive activities over a long period toward sustainable development in the concrete-based construction sector [6]. Please note Table 1 below for more demonstrations.

Sustainable development strategy	Practices
Saving resources/ energy and reducing emissions from cement and concrete manufacturing plants	Improving energy efficiency [42]. Using biofuels [43]. Replacing limestone with other high-calcium industrial by-products [44].
Reducing clinker content in cement and concrete	Utilizing more supplementary materials, such as Blast Furnace Slag (BFS), fly ash, natural pozzolans, and silica fume [45,46].
More precise design and determined use of concrete	Selecting the correct concretes for specific applications [47]. Recycling construction and demolition wastes to produce recycled aggregates [48,49]. Improving the durability of concrete [50].

Table 1: Practices toward sustainable development within the concrete construction sector.

Undoubtedly, the above-described approaches will enhance the concrete industry's sustainability as a whole. It should be understood that the environmental impact of a building is very sensitive to the construction material choices [33]. This paper review puts forward a key solution by utilizing BFRC in concrete-based buildings in terms of environmental impacts within the manufacturing and operational stages of buildings.

Therefore, to increase sustainable development within the concrete and cement construction sector through establishing the basis for sustainable structure based on sustainable innovative construction materials.

4 BFRC AS A PROMISING CONSTRUCTION MATERIAL

4.1 Fiber Reinforced Concrete Composites (FRCC)

Predictably, cement will remain the key material to serve the construction sector's needs. Thus, as a consequence, the concrete and cement worldwide industry sector contributes to the sustainability challenges regarding environmental impacts. According to the International Energy Agency (IEA), the main levers for cement and concrete producers are the increase in energy efficiency and the use of alternative materials. Noting that these new materials might be able to play a role as cement constituents or reinforcing-concrete materials in the future [41].

FRCC gained increasing attention within the construction industry due to its enhanced mechanical properties and improved durability [51]. It is a combination of cementitious matrix and discrete fibers, which work together to provide additional strength and reinforcement to the concrete [52]. Generally, in terms of structural performance, it is well-known that traditional concrete is brittle in nature and lacks sufficient tensile strength. By introducing fibers into the concrete matrix, these shortcomings can be overcome [51]. Introducing FRCC has led to significant advancements in the construction industry. Fibers can be added to various cementitious materials such as concrete, mortar, and geopolymer composites to enhance their performance [51,52]. The fibers used in these composites can be extracted of different types, including synthetic fibers (e.g., glass fibers, carbon fibers, aramid fibers), natural fibers (e.g., plant fibers, basalt fibers), and metallic fibers [53,54]. Highlighting that fiber technology is a versatile and effective method of enhancing construction materials. By adding fibers to building materials, the resulting materials can be made stronger, more durable, and more resistant to damage from weathering and other environmental factors. This can help to extend the lifespan of buildings and infrastructure, reduce the need for maintenance and repairs, and promote sustainability in the construction industry [55].

4.2 Basalt Fiber Reinforced Concrete (BFRC)

Basalt is a common extrusive volcanic rock. It is formed by the decompression of the melted lava. As a worldwide rock, it has long been known for its thermal and structural properties. Its fibers are like carbon fiber and fiberglass, but they have better physical-mechanical properties than fiberglass and are significantly cheaper than carbon fiber [56]. Basalt fibers are natural fibers derived mainly from basalt rocks, making them a natural material rather than a synthetic one. Basalt fibers are produced by exposing basalt stones to high temperatures with the intent of melting and converting them into fibers [57].

Among many other reinforcing fibers, basalt fiber has been the least studied fiber [58]. The history of basalt fiber dates to 1923, and it was further improved during World War II. The United States and the Soviet Union investigated basalt fiber, especially for aerospace and military purposes [59]. Basalt fibers could not be widely used for other than military applications because of the political issues at that time. After 1995, and due to declassification, basalt fibers were produced and used on a commercial scale. Then, after 2000, scientific research on basalt fiber applications gradually increased. Today, the basalt fiber industry is improving based on the technology in composite research and applications that improved day by day. Basalt fiber is considered a viable alternative to traditional glass fiber by the composite industry. Therefore, many manufacturers and suppliers around the world are interested in basalt fiber, but with unlimited basalt reserves, Russia plays a key role in basalt fiber technology [60,61]. The Basalt fibers are manufactured mainly in Eastern Europe, Russia, and the USA, now in Israel, China, and India [62].

This review paper concentrates on a recent innovative constructional material, BFRC, which comprises the advantages of Basalt fibers technology and provides the opportunity to reduce energy consumption, limited resources consumption, and CO2 emissions, along with providing acceptable human welfare within buildings in harsh climates. Before detailing the properties of this new innovative material in terms of performance, it is worth introducing the state of the art with regard to its composition and manufacturing.

4.3 Composition of Basalt Fibers

BFRC is a type of fiber-reinforced concrete that utilizes basalt fibers to enhance the performance of plain concrete. The chemical composition of basalt fibers typically consists of significant proportions of SiO2 and Al2O3, followed by MgO, CaO, and iron oxides [63]. Fig. 2 shows the content of each component of basalt fibers. The proportion of SiO2 in the BF is nearly 51–59%, which provides good chemical stability and mechanical properties. Al2O3 is about 14–18%, which provides good thermal stability and durability. Also, iron oxides are generally 9–14%, which improves the high-temperature resistance of the fiber. Basalt fiber is a silicate material, and its characteristics are very similar to those of cement-based materials; therefore, it has been widely used in cement concrete recently [66].

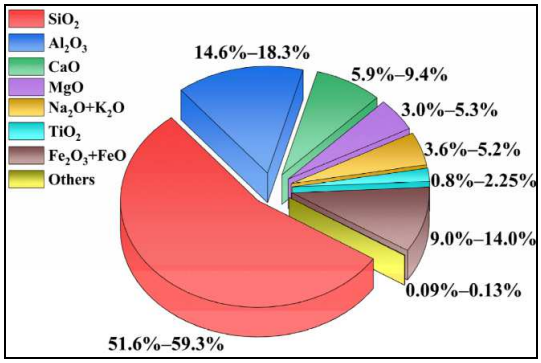

Fig. 2. Chemical composition of basalt fiber [66,67].

It should be noted that Basalt is distributed in many regions of the world, such as Russia, Indonesia, and the western United States, and there are abundant reserves in almost every province in China. As well as it constitutes an al large area of the Sham region in the middle east. Therefore, the specific chemical composition of BF will vary according to the geographical location of the basalt stone [66,67]. It is important to note that the primary component of BFRC is concrete, which consists of cement, aggregates, water, and various admixtures. The basalt fibers are added as a reinforcement material to the concrete mix, typically in the form of short fibers or continuous filaments. The proportions and specific composition of the concrete mixture can vary based on the desired performance characteristics and application requirements of BFRC [68]. There are different types of basalt fibers that can be added to concrete, such as chopped fibers or continuous fibers. The addition of basalt fibers can improve the mechanical properties of concrete, including compressive strength, flexural strength, and toughness, depending on the fiber content and the fiber-matrix interface. BFRC can also be used to produce precast concrete products, such as panels, pipes, and slabs. Basalt fibers have also been used for external reinforcement and retrofitting of concrete structures [69].

4.4 Manufacturing of BFRC

The manufacturing process of BFRC typically involves several steps. Firstly, basalt Fiber Production where the basalt fibers are manufactured mainly from basalt rock. The rock is mined from selected excavations and then washed. Afterward, the basalt rock is melted at a temperature of around 1400°C to produce molten basalt. The molten basalt is then drawn into fine fibers through a spinning process similar to that used for glass fiber production [70]. The second step is the concrete mixture preparation which combines cement, aggregates (such as sand and crushed stone), water, and any necessary admixtures. In the case of BFRC, chopped basalt fibers are added to the concrete mixture as a reinforcement material [71]. Then the mixing step comes where the concrete ingredients, including basalt fibers, are mixed thoroughly to achieve a uniform distribution of fibers within the concrete matrix [72]. Afterward, the casting step proceeds where the resulting BFRC is cast into the desired formwork or molds. This could involve pouring the concrete into structural elements such as beams, columns, or slabs, depending on the specific building application. Finally, the BFRC needs to undergo a curing process to allow the concrete to harden and gain strength. Curing involves maintaining proper temperature and moisture conditions for an appropriate duration. This manufacturing process which relies on mixing in the first place translated into taking advantage of the excellent mechanical properties of basalt fibers and combining them with the properties of concrete, resulting in a composite material with enhanced tensile strength, flexural resistance, and durability. The environmentally friendly manufacturing process of basalt fibers further adds to their appeal for concrete reinforcement applications [73]. It's important to highlight those specific details of the manufacturing

process, such as the fiber content, mixing procedures, and curing conditions, which can vary depending on the desired properties and the specific application requirements in building construction.

4.5 Properties of BFRC

It is worth reminding that the BFRC is the result of mixing concrete and basalt fibers. Thus, the advantage of properties of those two materials is considered in BFRC, whether they are directed to structural purposes or environmental purposes which is the point to be highlighted in this review paper. Additionally, noting that the BFRC as a new innovative material within the field of building construction sector was found to focus on strengthening the concrete structurally in the first place. Therefore, this section starts with concluding the basalt fiber's and BFRC's mechanical properties and then turn to the focal point in this paper; the potential benefits of BFRC within the environmental performance. This combines the sustainable perspective of this new material by highlighting how to assess the impact of such a new innovative material.

4.5.1 Mechanical properties and structural performance

As mentioned previously, the BFRC is a result of mixing basalt fibers and concrete, the BFRC took advantage in terms of the mechanical properties of the two mixed materials which already translated as structural performance in the building construction field. Indeed, there are quite a number of recent studies have been conducted to investigate the mechanical and structural properties of BFRC. For example, but not limited to, Al-Rousan, Khalid, and Rahman (2023) summarize their research findings on the properties of basalt fibers, including their mechanical properties. They discuss the effects of parameters such as fiber content and length on the structural properties of BFRC [74]. Also, another study held by Bheel (2021) explored the structural properties of BFRC, including compressive strength, tensile strength, flexural strength, and modulus of elasticity. It examines the effects of mechanical properties such as volume fraction and length of basalt fibers on these mentioned structural properties [71]. A review held by Zheng, et al (2022) suggested mechanical properties of basalt fibers enhance the structural properties of concrete by strengthening it at a microscopic level and bridging cracks due to its high elastic modulus and tensile strength [75]. Additionally, an investigational study by Wu, et al (2023) focused on the structural properties of BFRC by highlighting the basalt's natural properties, such as density, solidness, and high melting temperature. They emphasize basalt fiber's potential as a reinforcement in concrete structures [76]. Overall, those types of studies offer valuable insights into the mechanical and structural properties of BFRC and can serve as references for further exploration in this field.

Based on the related literature, we can conclude some key mechanical and structural properties that BFRC exhibits. Noting that the mechanical and structural properties can vary depending on factors such as fiber content, fiber length, concrete composition, and testing methods. As indicated previously within this section, it is worth to consider the key mechanical properties of BFRC before demonstrating the structural characteristics, as the last depends on the first. Basalt fiber reinforced concrete (BFRC) exhibits improved mechanical properties compared to plain concrete. The addition of basalt fibers enhances the cohesion and adhesiveness of the concrete, affecting its workability [70]. Also, BFRC shows increased compressive strength, which is an important indicator of concrete quality. The length and amount of basalt fibers influence the compressive strength of BFRC. The addition of basalt fibers can affect the modulus of elasticity (Young's modulus) of concrete, which is a measure of its stiffness. Noting that different proportions of basalt fibers can impact Young's modulus of BFRC [71]. Worth mentioning also that Basalt fiber-reinforced geopolymer concrete demonstrates improved impact mechanical properties, including dynamic compressive strength, deformation, and energy absorption capacity [77]. Basalt fiber reinforcement improves the structural properties of concrete by enhancing its mechanical performance, durability, and resistance to high temperatures, acids, and alkalis [75,78]. To highlight the potential of basalt fiber reinforcement in concrete structures, the post-cracking mechanical behavior of concrete reinforced with basalt fibers is comparable to that of steel fibers [73]. Eventually, concluding that the mechanical properties and synergistic mechanism of basalt fiber and concrete matrix under different temperatures can be evaluated to assess the structural performance of BFRC [79]. At this point of the review, highlighting that the evaluation of mechanical properties under different conditions to assess the structural performance would be useful for exploring of how to assess the environmental performance of BFRC within the building construction field.

4.5.2 Thermal properties and environmental performance

As mentioned previously, to meet sustainability targets, it is essential to mitigate the environmental effect of concrete structures. Thus, the main purpose of the construction industry is to develop a durable and strong sustainable concrete structure that can decrease the negative impact on the environment through minimizing the consumption of energy, limited resources, along with increasing the human welfare and protecting the future generations' welfare.

In fact, in the related literature in the field of the environmental performance of the building, there is a strong relationship between the thermal properties of construction materials and their environmental performance [80,81,82,83]. Where the related studies referred to several key points to consider in this relationship. For example, thermal conductivity and energy efficiency. The thermal conductivity of a material measures its ability to conduct heat. When it comes to buildings, it is preferable for thermal conductivity to be moderate in relation to materials with high thermal mass. This helps with the absorption and release of heat, aligning with the cooling and heating cycles of the building, and promoting energy efficiency [84]. Additionally, thermal insulation materials play a vital role in reducing the dependence on heating, ventilation, and air conditioning (HVAC) systems in buildings. Properly applied thermal insulation products retard the rate of heat flow by conduction, convection, and radiation, contributing to improved energy efficiency [85]. Also, one of the thermal properties is the moisture which can degrade the performance of insulating materials. When measuring the thermal conductivity of insulating materials, the drying conditions (temperature and time) are important factors to consider [86]. It is important to say that the environmental performance of a material can be influenced by its thermal properties. For example, materials with low thermal conductivity can contribute to energy-efficient designs and reduce heat transfer between different environmental compartments. Furthermore, there are other considerations that should be considered. It's important to note that thermal properties alone may not fully determine the environmental performance of a material. Other factors such as embodied energy, durability, recyclability, and life cycle analysis should also be considered when assessing the overall environmental impact of a material or a building [87].

At this stage of this section, it is worth to conclude the thermal properties of basalt fiber and BFRC in order to put forward the potential benefits of BFRC within the field of a building's environmental performance. A very potential benefit in the field of environmental performance is that the addition of basalt fibers to concrete has been found to reduce its thermal conductivity. BFRC exhibits lower thermal conductivity compared to conventional concrete, making it more resistant to heat transfer. Thus, it enhances the decrease of energy consumption. Related studies have examined the heat transfer characteristics of BFRC and observed improvements in heat transfer resistance compared to plain concrete [88,89]. Overall and besides the mechanical properties, investigations into the thermal properties of BFRC have shown promising results that can open new horizons in the field of sustainable building construction. Basalt fiber reinforcement contributes to lower thermal conductivity, improved heat transfer resistance, increased compressive strength, and enhanced durability, making it a potentially favorable material for various construction applications [71,76,79,88]. It is important to note that the specific properties of BFRC may vary based on factors such as the volume fraction of basalt fibers, mix design, curing conditions, and testing methods employed in different studies. Therefore, further research and specific testing are necessary to fully understand and optimize the thermal properties of BFRC for specific applications within the sustainable construction field. As a conclusion of this section, a hint that can be given to further future research in the field of BFRC-based buildings is that to enrich the environmental performance of such buildings, a great focus should be given to monitoring the thermal properties of enhanced materials such as BFRC. Therefore, to reach sustainable development targets within the sustainable building construction field and particularly in harsh climates where the need for energy consumption is at its peak.

4.6 Sustainable perspectives of BFRC

The sustainable perspectives in this section highlight the potential benefits of utilizing BFRC in the field of building construction. By leveraging its eco-friendly nature, improved performance, waste utilization, and energy efficiency. The raw material of basalt fiber originates from natural volcanic rock, which is low-cost extraction since they are found on the surface, there is no need to expend energy. Also, it incorporates high chemical and thermal stability and produces no harmful gas or waste residue in the fiber production process. It is a kind of new green material that meets the requirements of environmental protection; it is a kind of

green fiber that does not create environmental pollution or pose a cancer risk, Basalt fibers have a low carbon footprint and are environmentally safe and non-toxic. Also, the strength of basalt fiber is much higher than that of synthetic fiber. More to include is that its elastic modulus is similar to carbon's fiber, which is higher than that of other fibers. Though their comprehensive performance is parallel, the cost of basalt fiber is lower than one-tenth of carbon fiber [90,91,92,93].

Furthermore, Basalt fiber technology is a versatile and effective method of enhancing construction materials. By adding basalt fibers to building materials, the resulting materials can be made stronger, more durable, and more resistant to damage from weathering and other environmental factors. This can help to extend the lifespan of buildings and infrastructure, reduce the need for maintenance and repairs, and promote sustainability in the construction industry [73,94,95,96]. Additionally, the following Table 2 can conclude the key points of BFRC's sustainable perspectives in the field of building construction.

Sustainable perspectives	Illustration
Sustainable and eco-friendly material	Basalt fiber is derived from basalt rock, which is formed from volcanic eruptions. It is considered a green fiber because it has a minimal environmental impact and does not cause pollution during production. This makes it an attractive choice for sustainable construction practices [97].
Improved performance and durability	BFRC exhibits high elastic modulus, fracture strength, frost resistance, and corrosion resistance. By incorporating basalt fibers into concrete, the resulting composite material can enhance the performance and durability of structures, reducing the need for frequent repairs or replacements [97].
Reduced environmental footprint	The use of basalt fibers in concrete can contribute to the reduction of carbon emissions and energy consumption. Basalt fibers have a lower carbon footprint compared to other reinforcement materials like steel fibers, as their production requires less energy and generates fewer greenhouse gas emissions [71].
Improved energy efficiency	The use of BFRC can contribute to the thermal efficiency of buildings. Basalt fibers have good insulating properties, which can help reduce energy consumption for heating and cooling purposes [98].
Longevity and reduced maintenance	BFRC has the potential to extend the service life of structures due to its enhanced durability and resistance to environmental factors. This can result in reduced maintenance requirements, lower life-cycle costs, and a smaller environmental impact over the long term [99].

Table 2: Practices toward sustainable development within the concrete construction sector.

5 CONCLUDING REMARKS

Facing the new sustainability challenges resulting from construction materials, a detailed description of material alternatives needs to be provided. Future research studies aimed at the modification and optimization of building materials should include, at least, simplified environmental analysis, since the mitigation of environmental impact represents a major challenge for the sustainability of modern society. The eco-efficiency of the modern building corresponds not only to decrease energy consumption but also to the environmental impacts including resource consumption and human welfare should also be counted.

In conclusion, this paper indicated the related studies that explored and investigated the features of BFRC in the field of construction buildings, that particularly found encouraging results. However, most of the related research focused on mechanical properties and structural performance, while Studies focusing on thermal properties and environmental performance have been modest and still sketchy. Therefore, in the field of environmental performance for a BFRC-based building, the collected information is still scattered. Thus, this paper draws hints at how to evaluate the environmental performance of such buildings as well as drives for potential environmental benefits of utilizing BFRC in order to face the sustainability challenges mentioned earlier in this paper.

The challenge of reducing energy and raw material consumption and at the same time complying with human welfare, quality, and cost requirements in the context of the huge demand for cement as a construction material in the future will only be met with highly efficient research in the field of assessing the environmental performance. Overall, BFRC is a novel and promising green material with excellent capabilities and will have a lot of promise in the sustainable construction sector. Both sides of performance, the structural and environmental, should be considered.

Eventually, this review paper recommends further experimental research on the composition of basalt fiber in terms of basic materials that enhance the environmental performance of BFRC, and the building's environmental performance in turn. As the same for what has been studied previously in terms of BFRC's structural performance. With noting the different conditions that could be exposed to through manufacturing

the BFRC. Which affects the thermal parameters for these basalt fiber compositions. Then, to conclude the suitable conditions for reaching the best environmental performance of the BFRC-based building. Which can be evaluated based on operational and use periods, therefore enhancing the sustainable development of the concrete industry.

6 REFERENCES

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Vereinbarkeit von ganzheitlich gedachter Ökologie und Ökonomie in einem Gewerbequartier

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1 ABSTRACT

Die Kommunen Jülich, Niederzier und Titz sowie der Kreis Düren entwickeln ein 52 ha großes interkommunales Gewerbegebiet, den Brainergy Park. Ziel ist es, mit diesem Leuchtturmprojekt im Rheinischen Revier 4.000 Arbeitsplätze anzusiedeln, mit besonderem Fokus auf die Bereiche nachhaltige Energie, Bioökonomie und Digitalisierung unter Einbindung der lokalen Forschungs- und Startup-Landschaft. Entsprechend wurde neben einer dekarbonisierten energetischen Versorgung der Fokus auf eine nachhaltige Erschließung von Anfang an gelegt; hierzu waren die relevanten stake-holder zu identifizieren und frühzeitig anzusprechen und einzubinden. Die lokal vorhandene Expertise aus der Wissenschaft und Forschungslandschaft, namentlich die RWTH Aachen, FH Aachen am Standort Jülich, Deutsches Zentrum für Luft- und Raumfahrt, Helmholtz-Institut, Fraunhofer-Institut, Forschungszentrum Jülich um nur einige zu nennen, sollte ergänzt werden um Versorgungsansätze von innovativen Akteuren aus dem Energieversorgungsbereich. Denn es sollte ja nicht nur Ideen geäußert, sondern diese auch in Planungsvorschläge überführt, mit Erfahrung angereichert und dann zur Umsetzung gebracht werden. Gleichsam soll die Erschließung ökologischen Ansätzen folgen und die eigenen Gebäude des Brainergy Parks wie Brainergy Hub, start-up Village sowie die Energiezentrale durch ihre nachhaltige Errichtung und Betrieb Vorbild sein und bei den weiteren Investoren zur Nachahmung anregen.

Keywords: dekarbonisierte Energieversorgung, Gewerbequartierserschließung, Vereinbarkeit Ökologie und Ökonomie, Innovation und neue Geschäftsmodelle, Start-up-Szene

2 ENERGETISCHES VERSORGUNGSKONZEPT

Entsprechend durfte E.ON Energy Solutions GmbH als Konsortialführer seit 2021 zusammen mit den Unternehmen Fichtner, Stadtwerke Jülich, pbs Energiesysteme sowie dem Startup heatbeat als ARGE „set4“ nach gewonnener europaweiter Ausschreibung zusammen mit dem Auftraggeber Brainergy Park Jülich ein nachhaltiges, integriertes und resilientes Energie-Versorgungskonzept mit dem Ziel entwickeln, Energieversorgungsansätze von morgen unter Beachtung neuer Technologien, der digitalen Vernetzung sowie der Ausarbeitung von zukunftsoffenen Geschäftsmodellen für das Leuchtturmprojekt skalierbar darzustellen. „Toll ist,“ so Dr. Brauckmann als Konsortialführer von der E.ON Energy Solutions GmbH, „dass wir als E.ON gerade in der Herzkammer der deutschen Energieversorgung, dem Rheinischen Revier, als EVU den Strukturwandel bei solch einem Leuchtturmprojekt aktiv unterstützen dürfen.“

Gefördert wurden die vorbereitenden Arbeiten des Brainergy Parks unter anderem aus Mitteln des Ministeriums für Wirtschaft, Industrie, Klimaschutz und Energie des Landes Nordrhein-Westfalen. Erfreulicherweise wurde in 2023 ein entsprechender Förderantrag für das rd. 50 Mio.€ umfassende Investitionsvorhaben vom Bundesministerium für Wirtschaft und Klimaschutz über das BAFA, Förderprogramm BEW in Höhe von 19,2 Mio. € als bisher größte Einzelförderung bewilligt.

Als technisches System hat man von Anfang an das Thema Dekarbonisierung und maximale lokale Nutzung von erneuerbarem Strom, also Strom aus Gewerbedach-PV- und Windkraftanlagen gedacht. Dr. Stichtenoth, technischer Leiter des Energiesystems am Brainergy Park: „Geplant ist ein über 5 km langes dekarbonisiertes Wärmenetz mit rund 40 dezentralen und zentralen Wärmepumpen sowie einem großen zentralen Eisspeicher für die rund 200.000 m² zu beheizende und zu kühlende Fläche. Das low-ex Wärme-/ Kühlungsnetz ist dabei als sogenanntes pro-sumer-Netz ausgelegt, soll also bei den Gewerbebetrieben entstehende Abwärmen für andere Gewerbebetriebe nutzbar machen.“ Um den entstehenden regionalen erneuerbaren Strom aus dem verpflichtenden Dach-PV- und ergänzend einzubindendem Windstrom optimal lokal zu nutzen, ist die Errichtung eines Betriebsstromnetzes nebst Stromspeicherlösungen zur direkten Integration geplant. Strom soll jedoch nicht nur ‘einfach‘ in einem großen LiIon-Speicher zeitverzögert nutzbar gemacht werden, sondern gerade auch sektorenkoppelnd in einem 24x8m großen Eisspeicher als auch einem 100.000 Liter großen Heißwasserspeicher mit einem 2-Mwel-Power-to-heat-Modul

zwischengespeichert werden. Der Eispeicher stellt dabei im Winter Wärme für das Low-Ex-Netz bereit und friert dabei zu Eis. „Dieses Eis wird im Sommer zur Kühlung der Gebäude verwendet. Gleichsam dient dieser multi-funktionale Speicher zur Kappung von Versorgungsspitzen als auch als Sammelbecken für bei Kunden über das low-ex aufgenommene und damit nutzbar gemachte Abwärme auf niedrigstem Temperaturniveau“, so Prof. Hoffschmidt, GF der Brainergy Park Jülich. Denn die Speicherung von Energie ist gerade mit dem Medium Wasser, zumal einzusetzen als Wärme- sowie Kühlungs-/Kältelieferant, am ökologischsten und ökonomischsten möglich. Wenn dies noch mit Wassertemperaturen von 8 Grad Celcius geschieht, ist dieses System auch äußerst effizient – kaum Energie entweicht in die Umwelt wie bei herkömmlichen Konzepten.

Freuen sich über den Empfang des Förderbescheides (v.l.n.r.): Axel Fuchs (Bürgermeister Stadt Jülich), Dr. Arndt Brauckmann (Projektleiter E.ON & GF Brainergy Park Energie), Katherina Reiche (CEO Westenergie), Anna Jasper-Martens (CEO EIS Germany/ E.ON), Prof. Dr. Hoffschmidt (GF Brainergy Park Jülich), Frank Rombey (Bürgermeister Gemeinde Niederzier) sowie Dr. Jochen Handke (GF E.ON ESY)

Die Geschäftsführung der Brainergy Park Energie GmbH (v.l.n.r.): Prof. Hoffschmidt, Dr. Brauckmann, Dr. Stichtenoth

Gerade die Verschaltung des Eisspeichers mit den fünf an zentraler Stelle geplanten, je 1,2 MW großen Wärmepumpen ermöglicht es, den in dem Gewerbepark entstehenden lokalen PV-Strom zur Entlastung des vorgelagerten Stromnetzes auch effektiv zu nutzen, ihn also nicht in das vorgelagerte Netz zur weiteren Verteilung mit ggf. hohen zusätzlich benötigten Netzausbaukosten ‘nur weiterzuleiten‘. „Gerade in der maximalen lokalen Nutzung dieses Stroms, aber auch in der Aufnahmemöglichkeit von im vorgelagerten Netz abgeregeltem Strom mit hohen Kosten für die Endkunden, liegt ein neuer Ansatz und volkswirtschaftlicher Effizienzgewinn gegenüber den bisherigen Angängen. Das wir dies als Brainergy Park nunmehr auch zusammen mit E.ON/Westenergie über das gemeinsame JV Brainergy Park Energie umsetzen dürfen, erfreut natürlich umso mehr – es ist ja ein gemeinsames Baby mit 3-jähriger Geburtszeit“, so Dr. Stichtenoth. Im Ergebnis sind gemäß Simulationsergebnissen geplant so rd. vier GW/h Wärme und fünf GW/h Kühlung pro Jahr dekarbonisiert zu produzieren. Weitere benötigte Mengen, insbesondere auch im Bereich der Kältelieferung oder Klimatisierung sowie Prozeßwärme abhängig von den sich ansiedelnden Kunden wurden nicht mit eingerechnet, aber möglich sowie damit zukunftsoffen in der Auslegung des Systems berücksichtigt. Entsprechend freuen sich die Gesellschafter der Brainergy Park Jülich, die E.ON/ Westenergie sowie die Brainergy Park Jülich, mit der Gründung des gemeinsamen Joint Ventures Brainergy

Park Energie gerade auch diese Aspekte von Anfang an mit berücksichtigt zu haben, um ein entsprechendes resilientes System getreu den Vorgaben ‘role-model und nicht nur Leuchtturm‘ auch sein zu können, entwickelt zu haben und für die sich ansiedelnden Investoren aus Forschung, Wissenschaft, Gewerbe und Verwaltung umzusetzen.

3 DIGITALE VERKNÜPFUNG UND STEUERUNG ALS BASIS FÜR ENERGIEEFFIZIENZ UND NEUE ANGEBOTE IM MOBILITÄTSBEREICH

Effizienzgewinne und weitere Vorteile sind jedoch nicht einfach nur durch „gute“ Technik wie den Einsatz von Wärmepumpen und Eisspeicher zu erreichen. „Übergreifend soll es eine optimale Vernetzung aller Erzeuger, Speicher und Verbraucher durch ein Digitales-Energie-Quartiers-Managementsystem geben; dieses wird“, so Dr. Brauckmann, „die Basis für die Verschneidung von ‘Energie und Daten‘ und damit von Energieeffizienz sowie weiteren Kunden-Dienstleistungsangeboten sein. Damit sind wir nicht nur Leuchtturm im Rheinischen Revier und darüber hinaus, sondern eben auch attraktiv für die sich ansiedelnden Unternehmen und Blaupause für kommende Projekte“. Denn bei dem Projekt in Jülich wurden nicht nur die Wärme-/Kühlungsangebote von Anfang an mitgedacht, sondern auch die Erschließung mittels eines gewerbeparkweiten Glasfasernetzes quasi als Autobahn für die Daten. Eben hierüber ist nicht nur das Echtzeit-Monitoring aller Erzeuger und Verbraucher möglich. Sondern es können eben auch Wetterdaten, allgemeine Erfahrungen resultierend aus dem Nutzerverhalten im eingeschwungenen Systemzustand sowie Effekte aus weiteren Sektoren wie der Mobilität zum einen zur Effizienzerhöhung auswertbar und durch Steuerung der verschiedenen, eigentlich autonomen technischen Aggregate, nutzbar gemacht werden. Zum anderen schafft es eine für alle Kunden bis dato noch nicht für möglich gehaltene Transparenz der Energieversorgung, da in Echtzeit die Verbräuche sichtbar gemacht werden. Hierdurch wird eine Transparenz erreicht, die eine „einfache“ Energieeinsparung erst ermöglicht getreu dem Motto „jede eingesparte kWh ist die ökologischste, egal wie ökologisch diese hergestellt wurde“.

Auf dem beigefügten Foto (v.l.n.r.): Dr. Arndt Brauckmann, GF BPE; Prof. Dr. Bernhard Hoffschmidt, GF BPJ; Dr. Stefan Küppers, Vorstand Westenergie; Dr. Jochen Handke, GF E.ON Energy Solutions

Das hiermit auch Ansätze wie „predictive maintenance“ nicht nur zum Vorteil des Anlagenbetreibers Brainergy Park Energie möglich werden, sondern auch für die versorgten Endkunden, ist klar: „Bevor etwas kaputt geht, sollte das entsprechende Aggregat Auffälligkeiten durch eine Abweichung von technischen Solldaten zeigen und in der digitalen Leitwarte sichtbar sein. Hier kann man dann die Art des Defekts schon erahnen und einen Techniker, sofern der Fehler nicht via Fernaufschaltung behebbar ist, gleich mit den richtigen Ersatzteilen losschicken und die Reparatur effizient durchführen, bevor es zu Ausfällen kommt. Ein wichtiger Aspekt in einem Gewerbepark mit einem 24/7-Versorgungsanspruch“, so ist sich die Geschäftsführung der Brainergy Park Energie einig. Weitere Chancen hieraus können erahnt, aber bei der Rasanz der Entwicklung im IT-Bereich, gerade auch bei der Nutzung von KI, noch gar nicht hoch genug eingeschätzt werden; hier will man aber schon jetzt maximal zukunftssicher aufgestellt sein. „Hierdurch wird das Joint Venture zum „Daten- & Energiemanager 4.0“, eine Verschneidung von Energie und Daten zur Generierung ökonomischer wie ökologischer Vorteile zugunsten der Kunden und Role Model für zukünftige derartige Versorgungsansätze und weitere Dienstleistungsangebote und damit Geschäftschancen– das ist das Ziel“, so Dr. Brauckmann. Im Blick hat man dabei gerade auch das Thema E-Mobilität; denn neben

„einfachen“ Ladelösungen im Gewerbepark wird das Thema bi-direktionales Laden bereits mit angedacht und verfolgt. Das eigene Betriebsstromnetz mit der parallelen Vernetzung der Ladesäulen über das Glasfasernetz schafft neue Möglichkeiten, zeitabhängige Tarife während eines Überangebotes von lokalen EE-Strom anzubieten und die ‘diversen Batterien auf vier Räder‘ als für das Energiesystem nutzbare Speicher auch effizient einzusetzen; Geschäftsmodelle wie vehicle-2-grid, vehicle-2-home, vehicle-2-storage etc. sind in der Planung.

4 EINBINDUNG LOKALE FORSCHUNGSLANDSCHAFT UND START UPS

Nutzung der vorhandenen Expertise aus der Wissenschaft und Forschungslandschaft, so wurde es der Brainergy Park Jülich in das Stammbuch geschrieben. Zu nennen sind hier beispielhaft die RWTH Aachen, FH Aachen am Standort Jülich, Deutsches Zentrum für Luft- und Raumfahrt, Helmholtz-Institut, Fraunhofer-Institut, Forschungszentrum Jülich etc. „In Jülich gibt es eine Forschungslandschaft mit weltweitem Ruf – viele Forscher und Denker, die Know How und Ideen für Zukunftstechnologien entwickeln“, so Prof. Hoffschmidt. „Unter Einbindung der Ideen lokaler Startups sowie der Forschungslandschaft ist es uns mit E.ON als Partner gelungen, einen sehr guten ökologischen Fußabdruck des Wärmesystems mit einem Primärenergiefaktor von weniger als 0,1 als Planwert bei einer CO_2-Einsparung von 1.434 t/a, d. h. von 95 % gegenüber dem Referenzsystem BAFA/BEW-Förderung, zu planen.“ Damit wurde von Anfang an konsequent die Forschung und Wissenschaft mit eingebunden; auch hier ein Role-Model-Ansatz für zukünftige Quartiersentwicklungen.

Damit der Strukturwandel im Rheinischen Revier erfolgreicher als bei bisherigen Industrie- und Strukturtransformationsprozessen gelingt, soll zukünftig die Überführung dieser Ideen in neue Produkte, und damit in langfristig sichere Arbeitsplätze und dekarbonisierte Geschäftsmodelle, zudem noch besser gelingen. Entsprechend wird ein entsprechendes Ökosystem geschaffen, in dem sich Startups, junge Unternehmensgründungen und KMUs etablieren können und inter- und nationale Unternehmen sich ebenso ansiedeln wie große Forschungsinstitute. „Nun können wir“, so Dr. Brauckmann, „nunmehr zusammen mit dem Brainergy Park Jülich als gleichberechtigte Partner des Joint Ventures die weiteren Umsetzungsarbeiten für das dekarbonisierte Energiesystem vorantreiben und den zukünftigen Gewerbetreibenden nachhaltige und langfristig planbare Energie-Versorgungsangebote unterbreiten.“

5 NACHHALTIGE ERSCHLIEßUNG DES AREALS UND KUNDENANGEBOTE

Gerade nachhaltige Erschließungsangebote werden immer wichtiger, was auch die Resonanz aus den diversen geführten Kundengesprächen mit sich ansiedelnden Kunden bestätigt: „Grüne Energie-Versorgungsmöglichkeiten sind bis hin zum ‘kleineren Mittelständler‘ wichtig, denn er ist mit seinen Lieferungen häufig ein Teil eines größeren Produkts. Und dieses kann zunehmend nur mit seinem dokumentierten Gesamt-CO_2-Abdruck vermarktet werden – mithin durch unsere Super-Öko-Quoten ein weiterer, sogar international, Beachtung findender Ansiedlungsvorteil“, so Prof. Hoffschmidt.

Entsprechend diesem Ansatz einer dekarbonisierten Energieversorgung wurde auch das Thema nachhaltige Erschließung berücksichtigt: „Denn die vor 3 Jahren in der Politik angedachte Verpflichtung zur PV-mäßigen Nutzung aller geeigneten Dächer war für uns kein Hinderungsgrund. Es wurde die PV-mäßige energetische Erschließung der Dächer mit 80 % Eindeckungsverpflichtung für jeden Gewerbetreibenden zur Grundstücks-Kaufvertragsgrundlage gemacht; entsprechend waren diese Dachflächen nicht für eine Dachbegrünung und damit ökologische Nutzung o. ä. verfügbar“, so Dr. Brauckmann. Aber nur so können

große Mengen an lokalem erneuerbarem Strom gesichert werden; dieses war für einen Gewerbepark mit seinem Energiebedarf besonders wichtig.

„Entsprechend haben wir uns überlegt, wie dieser ‚Nachteil', auch wegen der Leuchtturmfunktion des Brainergy Park Jülich, für weitere Erschließungen", so Frank Drewes, GF Brainergy Park und Leiter Flächenvermarktung, „ausgeglichen werden konnte. Und so haben wir neben der Verpflichtung der Grundstückseigentümer zur oberflächennahen Versickerung des Niederschlagswassers 5 m breite Trassen links und rechts der Straßen geschaffen, welche nicht nur das Straßenwasser aufnehmen und in den Boden ableiten, sondern insbesondere auch begrünt sind bzw. zukünftig mit ökologisch wertvollen Gras- und Kräuterstrukturen versehen werden können." Hierdurch wird der Brainergy Park seinem Anspruch gerecht, lokal eine Vereinbarkeit von Ökologie und Ökonomie aufzuzeigen, d. h. finanzier- und umsetzbare Konzeptentwürfe darzustellen und beispielsweise gerade auch für die bekannte Thematik „Insektensterben aufhalten" Antworten zu liefern. Ein ureigenstes Interesse zudem vom Brainergy Park: Bereits letztes Jahr konnten die alten, im Park vorhandenen Streuobstwiese beerntet und die Früchte vergoren werden: „Der hieraus gebrannte BrainGeist ist ein beliebtes Andenken an einen Besuch am Brainergy Park mit seinen nachhaltigen und lokalen Versorgungsansätzen. Wenn aber die Obstbäume nicht mehr bestäubt würden, würde man dies sofort merken; gefährdete Befruchtungen der Früchte und damit möglichweise kein BrainGeist wären die Folgen", so Dr. Stichtenoth. Ein Thema, das breit in der Obst- und Landwirtschaft und damit für die gesamte Versorgungsstruktur in Deutschland und darüber hinaus diskutiert wird.

Um dem eigenen Anspruch, ein nachhaltiges Gewerbegebiet zu planen und umzusetzen, gerecht zu werden, wurde eine weitere Maßnahme ergriffen. Franziska Faßbender, Leiterin des Bereichs Architektur- und Hochbau im Brainergy Park Jülich, erläutert: „Wir hatten die Vision, ein zentrales Gebäude zu schaffen, das als Treffpunkt für die Brainergy Park Community, Startups, Scale-Ups, Gründungsinteressierte sowie innovative klein- und mittelständische Unternehmen dienen soll. Der Brainergy Hub ist mit einer Bruttogrundfläche von 9.728 m² das größte Einzelgebäude im Brainergy Park Jülich; insgesamt werden ja rund 40 Gebäude errichtet". Das Zentral-Gebäude soll als Leuchtturmprojekt im Strukturwandel Vorbildcharakter in Sachen Nachhaltigkeit, Flexibilität und innovative sowie kommunikative Arbeitswelten entwickeln. Entsprechend wurde ein Gebäudekonzept entwickelt, das ein Spannungsfeld zwischen kreativem Chaos und konzentriertem Arbeiten schafft. Hierfür wurden verschiedene bereits realisierte Konzepte in ganz Europa überprüft, teilweise persönlich besucht und die besten Detailkonzepte zu einem neuen Ganzen mit dem roten Faden des Brainergy Park Gedankens gedacht und geplant. So lässt sich bspw. durch das flexible Tragwerks- und Ausbauraster des Gebäudes dieses kontinuierlich veränderten Anforderungen und Entwicklungen der Nutzer anpassen. Das Innovations- und Gründerzentrum soll dabei als Landmarke im Brainergy Park Schnittstelle und Orientierungspunkt sein und zum informellen Austausch und zur Kommunikation der Nutzer anregen und so das Kreieren von Innovationen und Ideen fördern; also quasi die Idee des Brainergy Parks – Schaffung neuer Ideen zur Entwicklung neuer Geschäftschancen – im wahrsten Sinne auch als Gebäude verkörpern.

Damit aber nicht genug: „Selbstverständlich war es uns wichtig, gerade das Startup Village – Ort für Ansiedlung von Startups in 20 Kleinstgebäuden mit einem Zentralgebäude – nicht nur über nachhaltige Lösungen zu denken und daraus Geschäftsideen entwickeln zu lassen, sondern eben diese Gebäude auch nachhaltig herzustellen. Entsprechend sind sie vollständig aus Holz hergestellt und können dadurch, sofern nötig, problemlos anderweitig eingesetzt oder ganz im Sinne des Cradle-to-Cradle Prinzips wieder in ihre Einzelteile zerlegt werden", so Ingmar Stock, Leiter des Startup Village im Brainergy Park Jülich. Gerade durch die Verwendung von Holz soll gezeigt werden, dass eine Minimierung von grauer Energie und damit auch CO_2-Austausch beim Hausbau eingespart werden kann; hierdurch will man die diversen Investoren im Gewerbepark natürlich animieren, derartige Konzepte mit aufzugreifen.

Mit der Umsetzung all dieser Maßnahmen kann nunmehr begonnen werden: Als erstes hat das Startup Village seine Arbeit bereits in 2023 aufgenommen, das zentrale Hub-Gebäude als auch das Energiesystem werden bis 2026 errichtet, um die Aufsiedlung des innovativen Gewerbeparks bis 2030 zu unterstützen.

6 ERGEBNIS

Zusammenfassend lässt sich sagen: Brainergy Park Jülich – das Role Model für zukünftige Erschließungen mit dem Nachweis der Vereinbarkeit von ganzheitlich gedachter Ökologie und Ökonomie!

Wie bindet man seine Mitarbeitenden? Fördern die Arbeitgeberattraktivität und die betriebliche Gesundheitsförderung die Bleibemotivation der Mitarbeitenden? Eine quantitative Fragebogenstudie

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1 ABSTRACT

Mit einem Rekordhoch von zwei Millionen unbesetzten Arbeitsplätzen auf dem heutigen Arbeitsmarkt war die Notwendigkeit der Mitarbeiterbindung noch nie so relevant. Diese Studie untersucht die Beziehungen zwischen Arbeitgeberattraktivität und betrieblicher Gesundheitsförderung zu allgemeiner Arbeitszufriedenheit und Bleibemotivation, um die wichtigsten Schraubstellen für die Mitarbeiterbindung zu finden. Das erdachte Untersuchungsmodell dieser Studie orientiert sich hierbei an einem Modell von Dassler et al. (2022). Zwetsloot et al. (2010) und Suárez-Albanchez et al. (2021), sind ebenfalls für die Theoretische Einordnung der Variablen dieser Arbeit relevant. Die Daten wurden mittels eines Online-Fragebogens erhoben, an dem 116 Probanden teilnahmen und durch eine aus einem Vorjahr stammende Bachelorarbeit ergänzt, was zu einer Gesamtstichprobe von 212 Befragten führte. Für die Untersuchung der Arbeitgeberattraktivität wurde teilweise eine Skala von Zimber (unveröffentlicht, Hochschule der Wirtschaft für Management) verwendet. Unter den fünf Facetten der Arbeitgeberattraktivität zeigte sich unerwartet, dass der inhaltliche Anspruch negative Auswirkung auf die allgemeine Arbeitszufriedenheit hat, während sich die Soziale Interaktion als ein starker Prädiktor für eben diese herauskristallisierte. Zusätzlich trug die persönliche Entwicklung als stärkster Einfluss zur Vorhersage der Bleibemotivation bei. Die betriebliche Gesundheitsförderung spielt eine entscheidende Rolle bei der Steigerung der Bleibemotivation, ohne jedoch einen signifikanten Einfluss auf die allgemeine Arbeitszufriedenheit zu haben. Affectives Commitment erwies sich als entscheidender Mediator der Beziehungen der unabhängigen Variablen (Arbeitgeberattraktivität und betriebliche Gesundheitsförderung) zu den abhängigen Variablen (allgemeine Arbeitszufriedenheit und Bleibemotivation). Zusammenfassend betont diese Studie die Bedeutung von Arbeitgeberattraktivität und betrieblicher Gesundheitsförderung als Schwerpunkte zur Steigerung der Mitarbeiterbindung. Diese Faktoren zu priorisieren, um eine zufriedenere und engagiertere Belegschaft zu fördern wäre dementsprechend für Arbeitgebende empfehlenswert.

Keywords: Bleibemotivation, Betriebliche Gesundheitsförderung, Arbeitgeberattraktivität, Studie, Fragebogen

2 EINLEITUNG

Bedingt durch ein neues Rekordhoch von ca. zwei Millionen unbesetzten Arbeitsplätzen, gewinnt das Thema der Mitarbeiterbindung stetig an Relevanz (Bundesagentur für Arbeit, 2022b).

Es ergibt sich die Frage, was Arbeitgebende tun können, um ihre Angestellten möglichst effizient zu halten. Arbeitgeberattraktivität ist hierfür ein bereits umfangreich erforschtes Thema. Ebenso relevant und wenig erforscht, ist diesbezüglich die Betriebliche Gesundheitsförderung (BGF), welche auch Einfluss auf die Arbeitszufriedenheit und Bleibemotivation von Arbeitnehmenden haben kann (Zwetsloot et al., 2010). Diese Studie hat zum Ziel herauszufinden, inwiefern Arbeitgeberattraktivitätsfaktoren und BGF einen Einfluss auf allgemeine Arbeitszufriedenheit (AAZ) und Bleibemotivation haben. Dies führte zu folgender Forschungsfrage.

Welche Faktoren haben den stärksten Einfluss auf Arbeitszufriedenheit und Bleibemotivation?

3 THEORETISCHER UND EMPIRISCHER HINTERGRUND

Arbeitgeberattraktivität ist definiert als der Nutzen, den Arbeitnehmende in der Arbeit für ein bestimmtes Unternehmen sehen. Gemessen wird dies anhand eines Modells, indem folgende Dimensionen unterschieden werden: Social Value, Interest Value, Application Value, Development Value, Economic Value (Dassler et al., 2022). Diese wurden von Rietz, Lohaus und Klinge (2015) ins Deutsche wie folgt übersetzt und validiert:

soziale Interaktion (SI), inhaltlicher Anspruch (IA), Anwendbarkeit (AN), persönliche Entwicklung (PE) und ökonomischer Nutzen (ÖN).

Die SI beschreibt hierbei ein attraktiv gestaltetes Arbeitsumfeld, welches sich durch Spaß, gute kollegiale Beziehungen und eine positive Teamatmosphäre auszeichnet und diese gezielt fördert. IA bewertet das Ausmaß, in dem sich eine Person zu den Arbeitgebenden hingezogen fühlt, die ein spannendes Arbeitsumfeld und neuartige Arbeitsmethoden bieten sowie die Kreativität ihrer Mitarbeitenden fördern. AN definiert sich dadurch, Gelerntes anzuwenden sowie in einem humanitären und kundenorientierten Umfeld zu arbeiten. Unter PE wird das Ausmaß verstanden, zu der Förderung von Karriere Anerkennung, Selbstwertgefühl und Selbstvertrauen von Arbeitgebenden geboten wird. ÖN definiert sich als das Ausmaß, zu dem Arbeitgebende eine überdurchschnittliche Vergütung und Arbeitsplatzsicherheit bieten (Berthon et al., 2005).

Die Bleibemotivation ist ein deutscher Fachbegriff, welcher in der englischen Literatur mit Turnover Intention invertiert genutzt wird. Die Bleibemotivation beschreibt die Absicht bei den aktuellen Arbeitgebenden auch weiterhin beschäftigt bleiben zu wollen (Sousa-Poza und Henneberger, 2004).

Laut den Studien von Gomes, Ribeiro und Santos (2023) und Obediat (2019) erweist sich Arbeitgeberattraktivität als negativer Prädiktor für Turnover Intention und folglich als positiver Prädiktor für Bleibemotivation. Dassler et al. (2022) bestätigen ebenfalls, dass Arbeitgeberattraktivität die Mitarbeiterbindung positiv beeinflusst.

Wichtig anzumerken ist dabei, dass die Studien von Gomez et al. (2023) und Obediat (2019) Bleibemotivation und Arbeitgeberattraktivität anders operationalisiert haben als Dassler et al. (2022). Somit sind diese Studien und die daraus resultierenden Annahmen nur eingeschränkt miteinander vergleichbar.

Schlussfolgernd kann man davon ausgehen, dass Arbeitgeberattraktivitätsfaktoren einen positiven Einfluss auf die Bleibemotivation der Angestellten haben, woraus sich folgende Hypothese ableiten lässt:

H1: Die fünf Arbeitgeberattraktivitätsfaktoren SI (H1a), PE (H1b), IA (H1c), AN (H1d) und ÖN (H1e) korrelieren signifikant positiv mit Bleibemotivation und leisten einen signifikant positiven Vorhersagebeitrag.

AAZ definiert sich als die Bewertung der Arbeitsumstände durch die Arbeitnehmenden (Felfe und Six, 2006). Dassler et al. (2022) konnten in ihrer Metastudie feststellen, dass AAZ in zahlreichen Fällen als Ergebnis der intern wahrgenommenen Arbeitgeberattraktivität entsteht.

Die Studie von Aidan, Alibabaei und Mohammad (2018) zielt darauf ab, Auswirkungen einer Arbeitgebermarke auf die Arbeitszufriedenheit in der Telekommunikationsbranche zu analysieren. Dabei konnte festgestellt werden, dass die Attraktivität der Arbeitgebermarke eine positive und direkte Rolle bei der Steigerung von AAZ spielt.

Die Studie von Dalkılıç et al. (2017) untersuchte die organisatorische Attraktivität und die Arbeitszufriedenheit von Sportlehrern. Es konnte festgestellt werden, dass die Arbeitgeberattraktivität von den Lehrkräften als hoch eingestuft wurde und das Niveau der AAZ auch erhöht ist. Demnach postuliert sich ein positiver Zusammenhang zwischen Arbeitgeberattraktivität und AAZ.

Limitationen der Studien von Aidan et al. (2018) und Dalkılıç et al. (2017) sind, dass diese sich auf bestimmte Branchen beziehen und daher weniger repräsentativ für die Gesamtheit des Arbeitsmarktes sind.

Aus den Studien ist dennoch abzuleiten, dass Arbeitgeberattraktivität positiv mit AAZ zusammenhängt, woraus sich folgende Hypothese ableiten lässt:

H2: Die fünf Arbeitgeberattraktivitätsfaktoren SI (H2a), PE (H2b), IA (H2c), AN (H2d) und ÖN (H2e) korrelieren signifikant positiv mit AAZ und leisten einen signifikant positiven Vorhersagebeitrag

Diese Arbeit beschäftigt sich mit BGF, welche von dem in der Literatur häufiger genutzten Konzept des Gesundheitsmanagements (BGM) zu unterscheiden ist. BGF wird definiert als alle gemeinsamen, nicht gesetzlich vorgeschriebenen, Maßnahmen von Arbeitgebenden, Arbeitnehmenden und der Gesellschaft zur Verbesserung von Gesundheit und Wohlbefinden am Arbeitsplatz (Faller, 2018). BGM wird hingegen von Badura et al. (1999) als die betrieblichen Strukturen und Prozesse beschrieben, welche gesundheitsförderliche Maßnahmen generieren und entsprechendes Verhalten leiten.

Eine Studie aus dem Jahr 2010 von Zwetsloot et al. hat den Einfluss von BGF auf allgemeine organisatorische Vorteile untersucht. Die gesammelten Daten ergaben, dass die Maßnahmen zu BGF die Arbeitgeberattraktivität fördern.

Limitation dieser Studie ist, dass diese qualitativ geforscht hat und somit keine quantitativen Daten vorhanden sind.

Zusammenfassend ergeben sich aus den literarischen Informationen bezüglich BGF folgende Hypothese:

H3: BGF korreliert signifikant positiv mit den fünf Arbeitgeberattraktivitätsfaktoren SI (H3a), PE (H3b), IA (H3c), AN (H3d) und ÖN (H3e).

Bezüglich des Zusammenhangs von BGF zu Bleibemotivation und folglich AAZ hat die Studie von Suárez-Albanchez et al. (2021) Gesundheit am Arbeitsplatz (Engl. Occupational Health) in Zusammenhang mit Turnover Intention näher untersucht. Dabei konnte ein negativer Zusammenhang zwischen Occupational Health und Turnover Intention festgestellt werden. Auf Grund dieser Ergebnisse wird postuliert, dass sich eine Verbesserung der BGF positiv auf die Mitarbeiterbindung auswirkt. Eine weitere Studie von Liu et al. (2019) bestätigt diesen Zusammenhang. Kiliç, Selvi (2009) haben Occupational Health in Zusammenhang mit AAZ untersucht und dabei festgestellt, dass die AAZ bei höheren Gesundheitsrisiken abnimmt.

Limitationen dieser beiden Studien sind, dass diese nicht explizit BGF erheben, sondern Occupational Health. Somit ist die Vergleichbarkeit mit dem Konzept BGF leicht eingeschränkt.

Demnach gilt herauszufinden, inwiefern sich die Ergebnisse auf den Zusammenhang zwischen BGF und AAZ sowie Bleibemotivation übertragen lassen. Daraus ergibt sich folgende weitere Hypothese:

H4: BGF korreliert signifikant positiv mit Bleibemotivation (H4a) und AAZ (H4b) und leistet einen signifikant positiven Vorhersagebeitrag auf beide.

Ergänzend zu den bereits genannten Variablen befasst sich der nachfolgende Abschnitt mit deren Beziehungen zu affectivem Commitment (AC). Unter AC versteht man die emotionale Bindung, die Arbeitnehmende zu ihren Arbeitgebenden aufbauen (Aydogdu und Asikgil, 2011).

A'yuninnisa und Saptoto (2015) sowie Yücel (2012) stellen fest, dass Arbeitgeberattraktivität einen stark positiven Einfluss auf das AC der Arbeitnehmenden hat. Saha und Kumar (2018) stellten eine Korrelation von AC mit Job Satisfaction fest. Dassler et al. (2022) konnten einen Mediationseffekt von AC auf die Auswirkungen von Arbeitgeberattraktivität auf AAZ und Bleibemotivation feststellen.

Alle zu AC durchgeführten Studien haben leicht voneinander abweichende Definitionen für die in Bezug stehenden Variablen. Und obwohl die Ähnlichkeit auf dieselben unterliegenden Konzepte schließen lässt, könnte dies die Vergleichbarkeit der Studien einschränken.

Trotz der genannten Einschränkungen führten diese Befunde bezüglich AC zu der Postulation von folgender Hypothese:

H5: Die Beziehungen der Arbeitgeberattraktivitätsfaktoren und BGF zu Bleibemotivation und AAZ werden von AC mediiert.

Mostafa (2022) untersuchen den Unterschied in der Wahrnehmung der Arbeitgeberattraktivität in Abhängigkeit der demographischen Variablen. Dabei konnte festgesellt werden, dass Frauen soziale, entwicklungspolitische und ökonomische Werte (in absteigender Reihenfolge) für besonders wichtig halten. Bei Männern ist der ökonomische Wert am wichtigsten, gefolgt von sozialen und dann entwicklungspolitischen Interessen. Mostafas (2022) Ergebnisse reflektieren die psychologischen Unterschiede beider Geschlechter.

Bakanauskienė, Žalpytė, Vaikasienė (2014) untersuchen ob die Attribute der Arbeitgeberattraktivität in litauischen Organisationen mit den wahrgenommenen Erwartungen ihrer Mitarbeitenden übereinstimmen. Bei der Untersuchung konnten Unterschiede bezüglich des Geschlechts festgestellt werden. Dabei erwarten Frauen weniger attraktive Arbeitsbedingungen als Männer.

Die Metastudie von Dassler et al. (2022) konnte Geschlecht als einen starken Moderator für den Zusammenhang von Arbeitgeberattraktivität auf AAZ feststellen. Männer sind dabei stärker von der Reputation des Unternehmens, der Ausbildung und der Entwicklung betroffen als Frauen, welche hingegen stärkeren Anspruch an Work-Life-Balance, Corporate Social Responsibility und Unternehmenskultur stellen.

Limitation der genannten Studien sind, dass die fünf Faktoren von Arbeitgeberattraktivität nach Berthon et al. (2005) nicht verwendet wurden sowie, dass Stichproben aus unterschiedlichen Kulturen stammen. Auch hier ist somit die Vergleichbarkeit der Studien eingeschränkt.

Abgeleitet aus den Studien kann festgehalten werden, dass es Geschlechterunterschiede bei der Einstufung der Relevanz der einzelnen Arbeitgeberattraktivitätsfaktoren gibt. Demnach wird folgende Hypothese abgeleitet.

H6a: Es gibt signifikante Unterschiede bei den fünf Arbeitgebersttraktivitätsfaktoren bezüglich des Geschlechts.

Albinger und Freeman (2000) untersuchen die Auswirkungen von Corporate Social Performance eines Unternehmens auf dessen wahrgenommenen Attraktivität. Arbeitssuchende wurden dabei in zwei Gruppen eingeteilt, die sich hinsichtlich des Bildungsgrades unterschieden. Es konnte ein Unterschied festgestellt werden, nachdem Personen mit höherem Bildungsgrad mehr Wert auf nicht-materielle Aspekte der Arbeitgeberattraktivität legen.

Nach Bakanauskinė et al. (2014) werteten Probanden mit einem Bachelor oder höherem Abschluss, ihre Work-Life-Balance, effektives Konfliktmanagement, Feedback, Kreativitätsförderung und Anerkennung der Arbeit stärker als Personen mit einem niedrigeren Bildungsabschluss. Diese Facetten fallen unter die Arbeitgeberattraktivitätsfaktoren nach Berthon et al. (2005), auch wenn Arbeitgeberattraktivität anders operationalisiert wurde. Aus den Studien geht hervor, dass Personen mit unterschiedlichen Bildungsraden, Arbeitgeberattraktivität unterschiedlich gewichten, woraus sich folgende Hypothese ableiten lässt:

H6b: Es gibt signifikante Unterschiede bei den fünf Arbeitgeberattraktivitätsfaktoren bezüglich des Bildungsgrades.

Der Begriff Stimmung ist die deutsche Übersetzung von dem in der Psychologie verwendeten Begriff Affect (positive und negative). Stimmung ist die phänomenologische Erfahrung des "Fühlens", die mit Begriffen wie "freudig", "ängstlich" oder "traurig" beschrieben wird (Krohne et al., 1996). Es wird hierbei unterschieden zwischen Positive Affect (freudig erregt oder entschlossen) und Negative Affect (bekümmert oder feindselig) (Krohne et al., 1996).

Bachleitner und Weichbold (2007) stellten fest, dass jemandes Stimmung stetig Einfluss auf deren Antwortverhalten hat. Eid (1995) bestätigte, dass Antworten einer Person von der momentanen Stimmung beeinflusst werden. Somit könnte man schließen, dass Stimmung zu Bias im Antwortverhalten führt, was bei der Erhebung der oben aufgeführten Variablen zu berücksichtigen ist.

Abgeleitet aus den obigen Studien und angelehnt an das Modell von Dassler et al. (2022) wird folgendes Untersuchungsmodell abgeleitet:

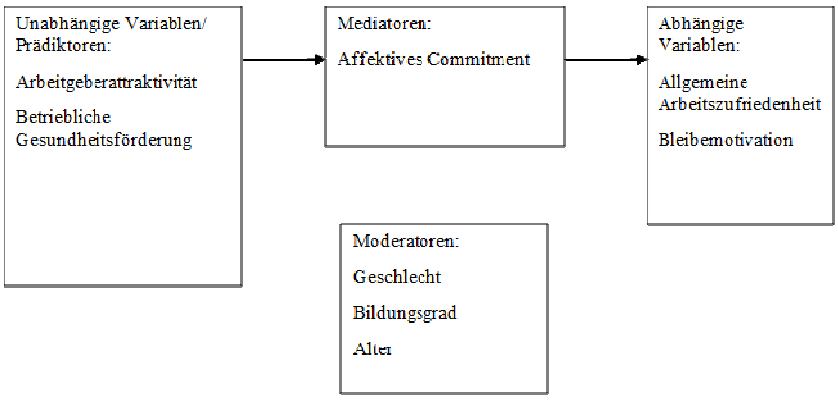

Fig. 1: Untersuchungsmodell

4 METHODE

4.1 Untersuchungsdurchfünrung

Dem Forschungsziel entsprechend wurde ein 59 Items und 17 Untersuchungsvariablen großer Fragebogen erstellt. Um eine möglichst große Teilnehmerzahl zu erreichen, wurde dieser als Onlinefragebogen über

einen Link in Sozialen Medien verteilt. Die Probanden konnten über den Zeitraum vom 16. Juni bis zum 05. Juli 2023 ihre Antworten zu den verschiedenen Items abgeben.

Zusätzlich zu der erhobenen Stichprobe, wurden auch Daten aus einer Studie aus einem vorangegangenem Jahr (Bachelorarbeit von Virginia Malitius) in die Auswertung mit einbezogen. Diese hat viele der Items, die auch im Fragebogen dieser Studie Verwendung fanden, genutzt.

4.2 Stichproben

Der Onlinefragebogen wurde insgesamt von 164 Probanden ausgefüllt. Hiervon haben 116 Teilnehmende den Fragebogen vollständig beantwortet und konnten somit in die statistische Auswertung miteinbezogen werden.

Die 116 Probanden waren im Durchschnitt 36,1 Jahre alt (min. 19, max. 78), bestanden aus 62 Frauen (53,4%), 41 Männern (35,3%) und 13 Teilnehmern, welche keine Angabe zu ihrem Geschlecht gemacht haben (11,2%). Einen Uni- oder Hochschulabschluss haben 68 der Probanden (58,6%), 17 (14,7%) haben eine abgeschlossene Berufsausbildung, 24 (20,7%) haben ein Fach-/Abitur, 3 (2,6%) haben einen Haupt-/Realschulabschluss und 4 (3,4%) einen anderen Abschluss. Keiner der Probanden hatte angegeben, kein Abschluss zu besitzen. Die Stichprobengröße von N=116 dient der Überprüfung der Hypothesen H5 und H6.

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Beide Stichproben zusammen ergaben eine Gesamtstichprobe von N=212 Probanden mit einem Durchschnittsalter von 33,2 Jahren (min. 18, max. 78). Hiervon sind 128 Frauen (60,3%), 70 Männer (33,0%) und 13 haben keine Angabe zu ihrem Geschlecht gemacht (6,1%). In der Bachelorarbeit wurde kein Bildungsabschluss der Probanden erhoben und somit ergeben sich für die N=212 Stichprobe diesbezüglich keine Daten. Die Stichprobengröße von N=212 dient der Überprüfung der Hypothesen H1, H2, H3 und H4.

4.3 Untersuchungsinstumente

Arbeitgeberattraktivität wurde mittels einer Skala durch 21 Items erhoben, welcher ein Teil eines von Zimber (unveröffentlicht, Hochschule der Wirtschaft für Management) entwickelten Fragebogens EAS_D2 ist. Dieser wiederum basiert auf der Employer Attractiveness Scale (EAS) (Berthon et al., 2005) und deren Übersetzung ins Deutsche EAS_D (32 Items) (Rietz et al., 2015). Die Items sind von den Teilnehmern jeweils auf einer Likert Skala (1=Trifft überhaupt nicht zu, 7=Trifft vollkommen zu) einzuordnen. Die 21 Items ordnen sich dabei fünf Faktoren zu, die jeweils zu einer Variable zusammengefasst werden.

Zusätzlich zur Erhebung der Arbeitgeberattraktivität wurde die wahrgenommene Qualität der BGF anhand vier Items aus einer Skala von O'Reilly, Chatman und Caldwell (1991) erhoben. Auch diese wurden von den Teilnehmern jeweils auf einer Likert Skala (1=Trift überhaupt nicht zu, 7=Trift vollkommen zu) eingeordnet.

AAZ wurde mittels einer Single-Item-Skala von Neuberger und Allerbeck (1978) erhoben. Die Bleibemotivation wurde mittels zwei Items erhoben, von welchen eines in Zeiteinheiten wiedergibt, wie lange ein Proband zum Zeitpunkt der Erhebung gedenkt bei seinen aktuellen Arbeitgebenden zu bleiben (0-1 Jahr; 2-5 Jahre; 6-10 Jahre; 11+ Jahre; bis zur Berentung). Das andere wiederum stuft auf einer Likert Skala (1=Trifft überhaupt nicht zu, 5=Trifft vollkommen zu) die subjektive Motivation des Probanden ein, bei den Arbeitgebenden zu bleiben (O'Reilly et al., 1991). Das AC wurde mittels fünf Items von Felfe et al. (2014) erhoben.

Geschlecht wurde erhoben, indem Probanden angaben, dass sie zum weiblichen oder zum männlichen Geschlecht gehören. Der höchste erreichte Bildungsabschluss der Probanden wurde nach Zuordnung in folgende Kategorien erhoben: keinen Abschluss, Haupt-/Realschulabschluss, Fach-/Abitur, abgeschlossene Berufsausbildung, Uni-/Hochschulabschluss und anderer Abschluss. Das Alter der Probanden sollten diese in einem offenen Antwortfeld in Jahren angeben.

Die Stimmung wurde zum Zwecke des Bias Ausgleichs mit dem 20-Itemlangen PANAS erhoben (Krohne et al., 1996).

Zur Auswertung der Rohdaten wurden verschiedene statistische Verfahren in der Statistiksoftware IBM SPSS Statistics (Version 27) durchgeführt. Für alle statistischen Testungen wurde hierbei ein Signifikanzniveau von .05 angenommen. Zuallererst wurden Reliabilitätsanalysen durchgeführt, um die innere Konsistenz aller verwendeten Skalen zu ermitteln. Im Anschluss wurden deskriptive Statistiken errechnet und einfache Korrelationsmatrizen zwischen allen Variablen erstellt. So sollten die Validitäten, die Zusammenhänge zwischen den Variablen und die Zweckmäßigkeit der Folgeanalysen abgeschätzt werden, sowie H3 überprüft werden. Darauffolgend wurden Regressionsanalysen durchgeführt, welche darauf abzielten, H1, H2 und H4, zu überprüfen. Um H5 zu prüfen, wurde mit Hilfe des PROCESS Macro Plug-in von Hayes (Hayes und Rockwood, 2017) eine Mediationsanalyse durchgeführt. Letztendlich wurden um H6 zu prüfen Einfaktorielle ANOVAs durchgeführt.

5 ERGEBNISSE

In der nachfolgenden Tabelle werden Stichprobengröße (N) Mittelwerte (M), Standardabweichungen (SD) und interne Konsistenzen (a) der einzelnen Skalen sowie deren Subskalen dieser Studie dargestellt.

Skala (Itemanzahl)	N	M	SD	Cronbachs Alpha (α)
Alter	210	33.2	13.3	
EAS-D2_SI[d]	211	5.70	1.06	.895
EAS-D2_PE[d]	211	5.17	1.18	.799
EAS-D2_IA[d]	212	5.25	1.26	.765
EAS-D2_AN[d]	212	5.20	1.12	.812
EAS-D2_ÖN[d]	211	4.56	1.62	.847
BGF[d]	208	4.08	1.57	.763
Zufried2[d]	205	5.4	1.4	
COBB[d]	210	3.55	.88	.861
Bleibemotivation[a]	207	3.17	1.2	.624
PANAS_pos[a]	110	32.75	8.33	.922
PANAS_neg[a]	112	16.39	6.36	.892

Fig2. Deskriptive Statistik; aMin. =1, Max.=5, dMin.=1, Max.=7; Subskalen sind mit _ gekennzeichnet.

Die nachfolgende Tabelle veranschaulicht die Korrelationen zwischen den einzelnen berücksichtigten Variablen.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Welches Geschlecht haben Sie?		.020		-.045	-.038	-.024	-.027	.158*	.043	.025	.057	-.047	.052	-.049
2 Wie alt sind Sie?	-.108			-.082	.002	-.046	.014	.014	.123	.141	-.142	.077	.102	.393**
3 Jahre in der Organisation	-.055	.666**												
4 Soziale Interaktion	.070	-.061	-.080		.634**	.568**	.510**	.298**	.253**	.504**	-.460**	.559**	.622**	.400**
5 Persönliche Entwicklung	.039	.093	.145	.645**		.554**	.514**	.362**	.312**	.561**	-.249**	.483**	.642**	.486**
6 Inhaltlicher Anspruch	-.039	-.023	.056	.533**	498**		.552**	.439**	.365**	.265**	-.226*	.399**	.492**	.276**
7 Anwendbarkeit	.061	.024	.203*	.445**	501**	.545**		.243**	.478**	.172	-.219*	.411**	.486**	.395**
8 Ökonomischer Nutzen	.256**	.080	.138	.279**	249**	.453**	.269**		.325**	.112	-.087	.255**	.422**	.287**
9 Angebote zur betrieblichen Gesundheitsförderung	.079	.117	.266**	.194*	.339**	.423**	.553**	.376**		.081	-.184	.328**	.363**	.386**
10 PANAS_posAff	.025	.141	.151	.504**	.561**	.265**	.172	.112	.081		-.250**	.514**	.488**	.395**
11 PANAS_negAff	.057	-.142	-.003	-.460**	-.249**	-.266*	-.219*	-.087	-.184	-.250**		-.389**	-.343**	-.245*
12 Alles in allem: Wie zufrieden sind Sie mit Ihrem Arbeitgeber	.097	.075	.125	.762**	.686**	.574**	.531**	.401**	.401**	.514**	-.389**		.704**	.559**
13 Affektives Commitment	.212*	.091	.164	.645**	.662**	.485**	.539**	.482**	.423**	.488**	-.343**	.827**		.675**
14 Bleibemotivation	.009	.462**	.492**	.422**	.567**	.255**	.403**	.311**	.380**	.395**	-.245*	.592**	.691**	

Fig.3. Interkorrelationstabelle; links unten N=116, rechts oben N=212; *a=.05; **a = .01; 0.3<r<0.5=schwach, 0.5<r<0.7=moderat, 0.7<r<0.9=stark, r>.9=sehr stark

5.1 Untersuchungsinstumente

Die Korrelationen für H1a bis H1e konnten alle vorläufig verifiziert werden und vier der fünf Faktoren leisteten eine signifikanten Vorhersagebeitrag auf Bleibemotivation. Somit konnte H1 vorläufig angenommen werden.

Der folgende Absatz beruht auf einem Datensatz mit N=116. Diese Ergebnisse wurden um mögliche Stimmungseffekte bereinigt. ÖN ist ein signifikant positiver Prädiktor für Bleibemotivation (B=.135, t(92)=2.365; p=.020). IA ist ein signifikant negativer Prädiktor für Bleibemotivation (B=-.211, t(92)=-2.091; p=.039). PE ist ein signifikant positiver Prädiktor für Bleibemotivation (B=.384, t(92)=2.935; p=.004). Die fünf Arbeitgeberattraktivitätsfaktoren erklären einen signifikanten Anteil der Varianz von Bleibemotivation (R2=.357; F(7,92)=7.292, p<.001).

Die Nachfolgenden Ergebnisse beruhen auf einer Stichprobengröße von N=212. SI ist ein signifikant positiver Prädiktor für Bleibemotivation (B=.199, t(192)=2.422; p=.016). PE ist ein signifikant positiver Prädiktor für Bleibemotivation (B=.320, t(192)=4.272; p<.001). IA ist ein signifikant negativer Prädiktor für Bleibemotivation (B=-.164, t(192)=-2.349; p=.020). Die fünf Arbeitgeberattraktivitätsfaktoren erklären einen signifikanten Anteil der Varianz von Bleibemotivation (R2=.455; F(7,192)=22.894, p<.001).

Die Korrelationen für H2a bis H2e konnten vorläufig vollständig verifiziert werden und zwei der fünf Faktoren leisteten eine signifikanten Vorhersagebeitrag auf AAZ und somit wurde H2 vorläufig teilweise angenommen.

Der folgende Absatz beruht auf einem Datensatz mit N=116. Diese Ergebnisse wurden um mögliche Stimmungseffekte bereinigt ÖN ist ein signifikant positiver Prädiktor für AAZ (B=.120, t(90)=2.427; p=.017). SI ist ein signifikant positiver Prädiktor für AAZ (B=.521, t(90) =4.579; p<.001). Die fünf Arbeitgeberattraktivitätsfaktoren erklären einen signifikanten Anteil der Varianz von AAZ (R2=.681; F(7,90)=27.385, p<.001).

Der folgende Absatz beruht auf einem Datensatz mit N=212. SI ist ein signifikant positiver Prädiktor für AAZ (B=.051, t(194)=4.842; p<.001). Die fünf Arbeitgeberattraktivitätsfaktoren erklären einen signifikanten Anteil der Varianz von AAZ (R2=.346; F(5,194)=17.136, p<.001).

Alle Hypothesen H3a bis H3e konnten vorläufig verifiziert werden, da jeder der einzelnen Faktoren positiv mit Angeboten zur BGF korreliert.

Der folgende Abschnitt beruht auf einem Datensatz mit N=212. Die Hypothese H4a konnte vorläufig verifiziert werden, da BGF moderat positiv mit Bleibemotivation korrelieret (Pearson-Korrelation r=.386, p<.001). BGF ist ein signifikant positiver Prädiktor für Bleibemotivation (B=.126, t(192)=2.616; p=.010). BGF erklärt einen signifikanten Anteil der Varianz von Bleibemotivation (R2=.455; F(7,192)=22.894, p<.001).

Der folgende Absatz beruht auf einem Datensatz mit N=212. Die Hypothese H4b konnte nicht verifiziert werden, da BGF keinen signifikanten Vorhersagebeitrag für AAZ leistet. BGF scheint kein signifikanter Prädiktor für AAZ (B=.109, t(7)=1.803; p=.073) zu sein.

Eine Mediationsanalyse wurde berechnet, um zu überprüfen, ob Arbeitgeberattraktivität Bleibemotivation vorhersagt und ob der direkte Pfad durch AC mediiert wird. Dabei wurde Arbeitgeberattraktivität mittels der einzelnen Faktoren betrachtet. Ein Effekt von SI (ß=-.0430, p<.001.), PE (ß=0.0923, p<.001.), IA (ß=-.0717, p<.001.), AN (ß=.0965, p<.001.), ÖN (ß=-.0004, p<.001.) auf Bleibemotivation konnte festgestellt werden. Nachdem der Mediator in das Modell aufgenommen wurde, sagte SI (ß=.5198, p<.001), PE (ß=.4793, p<.001), IA (ß=.3451, p<.001), AN (ß=.3803, p<.001), ÖN (ß=.2328, p<.001) den Mediator signifikant vorher. Auch war der Mediator ein signifikanter Prädiktor für Bleibemotivation, (SI: ß=.9461, p<.001; PE: ß=.8264, p<.001; IA: ß=.9615, p<.001, AN: ß=.8520, p<.001; ÖN: ß=.9073, p<.001). Damit konnte festgestellt werden, dass das Verhältnis zwischen Arbeitgeberattraktivität und Bleibemotivation von AC mit einem indirekten Effekt von (SI ab=0.4918, 95%-KI(0.3684, 0.6234); PE ab=0.3960, 95%-KI(0.2921, 0.5110; IA ab=0.3318, 95%-KI(0.2328, 0.4424); AN ab=0.3240, 95%-KI(0.2270, 0.4303); ÖN ab=0.2112, 95%-KI(0.1403, 0.2880)) vollständig mediiert wird.

Eine Mediationsanalyse wurde berechnet, um zu überprüfen, ob Arbeitgeberattraktivität AAZ vorhersagt und ob der direkte Pfad durch AC mediiert wird. Dabei wurde Arbeitgeberattraktivität und BGF mittels der einzelnen Faktoren betrachtet. Ein Effekt von SI (ß =.2607, p<.001.), PE (ß=.0526, p<.001.), IA (ß=.0855,

p<.001.), AN (ß=.1203, p<.001.), ÖN (ß=-.0247, p<.001.) und BGF (ß=.0770, p<.001.) auf Allgemeine Arbeitszufriedenheit konnte festgestellt werden. Nachdem der Mediator in das Modell aufgenommen wurde, sagte SI (ß=.5195, p<.001), PE (ß=.4814, p<.001), IA (ß=.3347, p<.001), AN (ß=.3734, p<.001), ÖN (ß=.2177, p<.001), BGF (ß=.2014, p<.001.) den Mediator signifikant vorher. Auch war der Mediator ein signifikanter Prädiktor für AAZ, (SI: ß=.9269, p<.001; PE: ß=1.0732, p<.001; IA: ß=1.0600, p<.001, AN: ß=1.0458, p<.001; ÖN: ß=1.1228, p<.001; BGF (ß=1.0710, p<.001.)). Damit konnte festgestellt werden, dass das Verhältnis zwischen Arbeitgeberattraktivität (mit Ausnahme von SI) und BGF zu AAZ von AC mit einem indirekten Effekt von (PE ab=0.5166, 95%-KI(0.3887, 0.6585); IA ab=0.3548, 95%-KI(0.2460, 0.4710); AN ab=0.3905, 95%-KI(0.2802, 0.5180); ÖN ab=0.2444, 95%-KI(0.1592, 0.3308); BGF ab=0.2156, 95%-KI(0.1312, 0.3012) vollständig mediiert wird.

Demnach wurden Mit Ausnahme der Beziehungen von BGF zu Bleibemotivation und von SI zu AAZ (teilweise mediiert) alle Beziehungen der unabhängigen Variablen zu den zwei abhängigen Variablen vollständig durch AC mediiert.

Die Hypothese H6a konnte vorläufig nur teilweise verifiziert werden. Bezüglich der Geschlechter unterscheidet sich nur ÖN signifikant (F(1,100)=6.990, p=.010). Die restlichen vier Arbeitgeberattraktivitätsfaktoren und BGF unterscheiden sich bezüglich des Geschlechtes nicht signifikant. Personen des männlichen Geschlechts werten den Ergebnissen entsprechend den ÖN stärker als weibliche Arbeitnehmende.

Auch die Hypothese H6b konnte vorläufig nur teilweise verifiziert werden. Bezüglich des Bildungsgrades unterschiedet sich IA (F(4,111)=3.302, p=.013) sowie AN (F(4,111)=2.914, p=.025) signifikant. Die restlichen drei Arbeitgeberattraktivitätsfaktoren und BGF unterschieden sich bezüglich des Bildungsgrades nicht signifikant. Folglich könnte man annehmen, dass je höher der erreichte Bildungsabschluss desto mehr Wert wird auf die beiden genannten Faktoren gelegt.

6 DISKUSSION

Diese Studie hat zum Ziel es für Arbeitgebende zu vereinfachen ihre Angestellten langfristiger halten zu können, indem sie gewisse Faktoren berücksichtigen. Hierzu wurden Arbeitgeberattraktivität und BGF hinsichtlich Bleibemotivation, AAZ mit AC als Mediator und demographischen Variablen Geschlecht und abgeschlossener Bildungsgrad untersucht.

Der Zusammenhang zwischen Arbeitgeberattraktivität und Bleibemotivation konnte für beide Stichprobengrößen vorläufig bestätigt werden, da alle fünf Faktoren der Arbeitgeberattraktivität positiv mit Bleibemotivation korrelieren. Die erstellten Regressionsmodelle bestätigen diesen Zusammenhang für ÖN (N=116), PE (N=116 und N=212) und SI (N=212). Zusätzlich wurde befunden, dass IA (N=116 und N=212) einen negativen Vorhersagebeitrag auf Bleibemotivation leistet. Schlussfolgernd könnte man davon ausgehen, dass je stärker die Ausprägung der Arbeitgeberattraktivitätsfaktoren (IA ausgenommen), desto höher die Bleibemotivation der Probanden.

Im Umkehrschluss folgt, wie von Gomes et al. (2023) und Obediat (2019) bereits belegt, dass wenn jemand mit gewissen Aspekten der Arbeitgeberattraktivitätsfaktoren nicht zufrieden ist, diese eher dazu neigen würde, die Arbeitgebenden zu verlassen. Könnten sich Mitarbeitende beispielsweise nicht ihren Anforderungen entsprechend weiterentwickeln, würden diese eher dazu tendieren anderswo Anstellung zu suchen.

Die verschiedenen Diskrepanzen zwischen den Regressionsmodellen der unterschiedlichen Stichprobengrößen, könnte sich intuitiv so erklären, dass für den Faktor ÖN der Altersunterschied zwischen den Stichproben hier den Ausschlag gibt. So könnte man davon ausgehen, dass weil die N=116 Stichprobe einen höheren Altersdurchschnitt aufweist die Teilnehmenden mehr Wert auf ihre Entlohnungen legen, da sich diese vermutlich eher in einer Lebensphase befinden, in der sie selbstständig für ihre Kostendeckung aufkommen müssen. Bezüglich der SI besteht die Möglichkeit, dass die Gewichtung der Probanden hier sehr stark mit der Stimmung zusammenhängt (Stimmungseffekte korrigiert bei N=116, nicht jedoch bei N=212). Somit sind mögliche Stimmungseffekte nicht auszuschließen.

Festzustellen ist jedoch, dass sich der negative Einfluss von IA und der positive Einfluss von PE in beiden Stichproben bestätigt, wobei der Einfluss der PE stets der gravierendste ist, weshalb es für Arbeitgebende ratsam wäre, auf diesen Aspekt das Hauptaugenmerk zu legen.

Der negative Einfluss von IA steht als einziger entgegen der Hypothese H1, was sich möglicherweise dadurch erklären lässt, dass wenn der IA zu hoch ist, Arbeitnehmende sich schnell überfordert fühlen und dadurch die Attraktivität ihrer Arbeitgebenden schlechter einschätzen.

Insgesamt stimmen die Ergebnisse dieser Studie, bezüglich Arbeitgeberattraktivität und Bleibemotivation, mit den Erkenntnissen der vorangegangenen Literatur (Gomes et al., 2023; Obediat, 2019; Dassler et al., 2022) zu Turnover Intention überein.

Der vermutete Zusammenhang zwischen Arbeitgeberattraktivität und AAZ konnte nur zum Teil bestätigt werden, da nicht alle Arbeitgeberattraktivitätsfaktoren mit AAZ positiv korrelieren. SI leistet dabei einen signifikanten Vorhersagebeitrag, die restlichen vier Faktoren weisen signifikante Korrelationen auf, leisten aber keinen Vorhersagebeitrag. Aus diesem Ergebnis lässt sich schlussfolgern, dass wenn der Faktor SI bei Mitarbeitenden erfüllt ist, diese tendenziell zufriedener mit ihrer Arbeit sind.

Herzuleiten ist dieses Ergebnis damit, dass Aspekte wie eine gute Kommunikation mit Kollegen und Vorgesetzten, ein gutes Arbeitsumfeld und kollegiale Beziehungen maßgeblich die Zufriedenheit beeinflussen.

Die Literatur kann Zusammenhänge zwischen Arbeitgeberattraktivität und AAZ bestätigen, (Dassler et al., 2022; Aidan et al., 2018 und Dalkılıç et al., 2017) gehen allerdings nicht näher auf SI ein.

Die postulierten Zusammenhänge zwischen Arbeitgeberattraktivität und BGF konnten einstweilig bestätigt werden. Dies lässt sich vermutlich dadurch erklären, dass wenn Arbeitgebende die Mittel haben, das eine zu fördern sie auch eher über die Ressourcen verfügen, um das andere zu fördern. Zwetsloot et al. (2010) bestätigt diesen Zusammenhang.

Der hypothesierte Zusammenhang zwischen Bleibemotivation und BGF (N=212) konnte vorläufig bestätigt werden. Ursache hierfür könnte sein, dass Arbeitnehmende die Wertigkeit von BGF erkennen, sowie sich der mangelnden Selbstverständlichkeit dieser bewusst sind und somit motiviert sind bei ihren Arbeitgebenden zu bleiben. Suárez-Albanchez et al. (2021) sowie Liu et al. (2019) bestätigen diesen Zusammenhang.

Für die Stichprobe N=116 allerdings wurde ein nicht signifikantes Regressionsmodell ausgewiesen. Gründe für die Diskrepanz der Ergebnisse könnten sein, dass die entsprechenden Daten nicht um die Stimmungseffekte korrigiert wurden.

Der postulierte Zusammenhang zwischen AAZ und BGF konnte nicht bestätigt werden. Ursachen hierfür könnten sein, dass die Unternehmen die Gesundheitsförderung der Mitarbeitenden nicht genug hervorheben. Zusätzlich veranlasst der durchschnittliche Arbeitstag Mitarbeitende nicht dazu sich täglich mit der BGF auseinanderzusetzen. Leider ist den Autoren keine Literatur bekannt, welche die genauen Ursachen hierfür identifizieren kann, weshalb die zuvor genannten Beispiele nur Vermutungen sind.

Während es widersprüchlich scheint, dass AAZ nicht von BGF beeinflusst wird während Bleibemotivation mit höherer Förderung der betrieblichen Gesundheitsmaßnahmen steigt, ließe sich diese Diskrepanz damit herleiten, dass der Nutzen von BGF Mitarbeitende eher rational bindet und somit AAZ welches ein eher emotionales Konstrukt ist nicht beeinflusst.

Die Hypothese H5 konnte zeitweilig angenommen werden da für alle postulierten Beziehungen der Arbeitgeberattraktivität und der BGF zu Bleibemotivation und AAZ entweder ein vollständiger oder teil Mediationseffekt gefunden wurde. In Bezug auf Bleibemotivation wurde festgestellt, dass der Einfluss aller Arbeitgeberattraktivitätsfaktoren vollständig durch AC mediiert werden. Dies könnte damit erkläret werden, dass eine Entscheidung zu bleiben zu einem großen Teil aus emotionalen Einflüssen hervorgeht (Allen und Meyer, 1990).

Der Einfluss von BGF auf Bleibemotivation hingegen wird nur teilweise mediiert, was bedeutet, dass BGF die Mitarbeitenden eher auf rationaler Ebene erreicht und weniger auf emotionaler. Dies bestätigt die obigen Vermutungen, dass AAZ ein eher auf Emotionen basiertes Konzept ist, während BGF tendenziell mehr rational Einfluss auf Arbeitnehmende nimmt. Der Einfluss von SI auf AAZ wird nur teilweise durch AC mediiert, was darauf schließen lassen könnte, dass jemandes soziale Beziehungen im Berufsumfeld zwar unabhängig von allem anderen die AAZ steigern könnte, allerdings nicht ausreichet um jemandes emotionale Bindungen zu dem Beruf als Ganzem zu beeinflussen. Der Einfluss der übrigen Arbeitgeberattraktivitätsfaktoren und von BGF werden vollständig von AC mediiert. Somit könnte man

argumentieren, dass AC ein ausschlaggebender Faktor in der Erhaltung von Arbeitnehmenden ist, welches sich durch Verbesserung der Attraktivitätsfaktoren und BGF steigern lässt.

Die Erkenntnisse dieser Studie decken sich mit den Befunden von A'yuninnisa und Saptoto (2015) und Dassler et al. (2022).

Die Hypothese H6a konnte einstweilig teilweise angenommen werden. Es wurde eine signifikante Korrelation zwischen ÖN und Geschlecht gefunden. Dies lässt sich vermutlich am ehesten dadurch erklären, dass Frauen heutzutage leider immer noch schlechter entlohnt werden als Männer (Bundesagentur für Arbeit 2022a).

Mostafa (2022) bestätigt den gefundenen Zusammenhang. Bakanauskiene et al. (2014) sowie Dassler et al. (2022) hingegen gehen davon aus, dass es im Gegensatz zu den Ergebnissen, weitere Faktoren gibt, nach welchen sich die Geschlechter unterscheiden.

Schlussfolgern lässt sich, dass es für Arbeitgebende eventuell wichtig sein könnte ein Auge auf Geschlechtsunabhängige Behandlungen und Entlohnungen zu haben.

Die Hypothese H6b kann auch nur partiell angenommen werden, da zwei der Arbeitgeberattraktivitätsfaktoren (IA und AN) sich signifikant bezüglich des Bildungsgrades unterscheiden. Festgestellt wurde, dass je höher jemandes Bildungsabschluss ist umso mehr Wert legt diese Person auf die beiden genannten Arbeitgeberattraktivitätsfaktoren, was die Arbeitgebenden dazu veranlassen sollte diese dem Bildungsabschluss der Arbeitnehmenden entsprechend anzupassen. Dies wird von Mostafa (2022), Albinger und Freeman (2000) und Bakanauskiene et al. (2014) bestätigt.

6.1 Limitationen und Implikationen für zukünftige Forschung

Die begrenzte Teilnehmerzahl, obwohl ausreichend für statistische Untersuchungen, mindert dennoch die Aussagekraft der Studie. Die unterschiedlichen Erhebungszeitpunkten beider Studien könnten ebenfalls zu Verzerrungen führen. Ein Großteil der Probanden stammt aus dem Umfeld der Autoren, weshalb die festgestellten Tendenzen eher repräsentativ für eine akademisch gebildete und jüngere Population sind als für die Gesamtheit der Arbeitnehmerpopulation. Des weiteren, ist anzumerken, dass die Erhebung von AAZ mit Hilfe einer Single-Item-Skala, obwohl valide, einer Erhebung durch mehrere Items in statistischer Aussagekraft nachsteht. Auch in dieser Studie ist nicht auszuschließen, dass Bias wie sozial erwünschtes Antwortverhalten oder mangelnde Motivation bei der Beantwortung der Items Einfluss auf die Daten genommen haben. Außerdem ist die Abschätzung des Effektes von BGF nur begrenzt möglich da kleinere Unternehmen weniger Mittel haben, um BGF zu betreiben, deren Angestellte also bei dieser Studie auch nur erschwert eine solche Umsetzung einschätzen können. Inhaltlich wurde in dieser Studie nicht zwischen verschiedenen Arten der Einstellung (z.B. Teilzeit oder Vollzeit, Präsenz- oder Homeoffice-Arbeit, etc.) unterschieden, ebenso wie viele mögliche andere Einflüsse auf die Einschätzungen der Arbeitgeberattraktivität oder der Bleibemotivation nicht mit untersucht wurden (z. B. kulturelle Unterschiede, religiöse Einflüsse, Gesundheitszustand der Probanden, etc.).

Weitere Forschung zu BGF scheint angebracht, in der beispielsweise die BGF bezüglich der Umsetzbarkeit sowie Zusammenhänge bezüglich Bleibemotivation näher betrachtet werden könnten. Ebenso könnten unterschiedliche Bildungsgrade und Berufsbranchen mit einer größeren Stichprobe näher untersucht werden, um differenzierter auf die jeweiligen Unterschiede einzugehen. Zudem könnten die Arbeitgeberattraktivitätsfaktoren kritisch reflektiert und bezüglich zusätzlicher potenzieller Einflüsse untersucht werden.

6.2 Praktische Implikationen

Die gewonnenen Ergebnisse belegen, dass die Attraktivitätsfaktoren einen starken Einfluss auf die Bleibemotivation und AAZ sowie auch das AC der Mitarbeitenden haben. Folglich wäre es sinnvoll in den Ausbau der einzelnen Arbeitgeberattraktivitätsfaktoren sowie BGF zu investieren, um mögliche Mitarbeiterfluktuation zu verringern.

Bezogen auf die Attraktivitätsfaktoren wären folgende Maßnahmen der Verbesserung dienlich (je nach Betriebsgröße und finanziellen Mitteln). Dabei gilt zu beachten, dass nicht alle Maßnahmen umgesetzt werden müssen, um diese Ziele zu erreichen. Um SI zu fördern sind nachweislich Kollegialität und Führungsstil entscheidend (Holste, 2012), dies kann durch beispielsweise teambuilding Events, regelmäßige

Betriebsfeiern, Teamsportaktivitäten und gemeinsame Mittagspausen gefördert werden. ÖN kann gefördert werden durch Organisation von Car-Sharing-Maßnahmen, der Ermöglichung von flexiblen Arbeitszeiten und dem Angebot von Kitas.Einer möglichen Überforderung der Aufgaben (IA) kann durch Feedbackgespräche entgegengewirkt werden. AN könnte berücksichtigt werden durch Recyclingauflagen, optimierte Materialnutzung, behindertengerechte Arbeitsumfelder und Einstellungsverfahren sowie der Unterstützung von Sozialprojekten (Ersoy und Aksehirli, 2015). PE kann gefördert werden durch Weiterbildungsangebote, wie Workshops, Seminare und Schulungen sowie Karriereförderung innerhalb des Unternehmens.

Zusätzlich könnte man durch die Ausweitung der BGF mittels Kooperationen mit Fitnessstudios, ergonomischen Stühle, höhenverstellbare Schreibtische sowie Teamsportaktivitäten, Massagen, Klimatisierung und einem pflanzenreichen Umfeld, die Arbeitszufriedenheit und Bleibemotivation steigern.

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Passive Cooling Technologies for Reducing the Heating of Containers

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1 ABSTRACT

Containers are widely used within the Bundeswehr, especially in military camps. These containers often overheat, most notably in southern areas. High temperatures can cause problems like accelerated ageing of stored material or failure of electronic equipment running inside. Air conditioning systems can counteract this but consume high amounts of energy and require regular maintenance.

Passive cooling technologies, i.e. technologies that cool without requiring additional energy, are intended to alleviate this problem. The simplest passive cooling technology is shading e.g. by applying additional roofing or camouflage nets. However, the disadvantages are the additional required material and the assembly and disassembly whenever the container is moved.

New technologies for passive cooling are based on different mechanisms: Coatings can reduce the solar heat-up either by being highly reflective or through a novel mechanism called passive daytime radiative cooling (PDRC). Another technique is the use of heat storage panels, which contain phase change material (PCM) to minimize the daytime heating of the containers. Furthermore, spacer fabrics on the surface of containers allow cooling based on the chimney effect.

To evaluate the passive cooling power of the different technologies, containers were equipped with three different cooling coating systems, heat storage panels, spacer fabrics, roofing and camouflage net. Two regular containers were used as a baseline. Temperature was measured at each container at different spots inside and outside. Further, every container was equipped with an air conditioning system and a power meter to measure energy consumption.

All containers with passive cooling technologies showed lower temperatures compared to the reference containers. The power measurements confirmed a lower energy consumption of the air-conditioning systems. PDRC coatings, PCMs und spacer fabrics show a better passive cooling power than shadowing like e.g. roofing. PDRC coatings were the most effective technology overall in this setup, but dependent on the application scenarios, the other passive cooling systems can also be powerful.

2 INTRODUCTION

In times of global warming, solutions for cooling down surfaces are widely asked. Within the Bundeswehr, surfaces of containers - especially in southern military operational areas - heat up fast, which also results in high temperatures inside the containers. This can lead to accelerated ageing of sensitive storage material or device failure due to overheating. Cooling by using air conditioning systems requires high energy consumption and regular maintenance of the devices. Especially in areas with weak infrastructure, the energy supply can only be guaranteed by diesel generators, which is why energy consumption should be as low as possible.

Passive cooling technologies, i.e. technologies that cool without requiring additional energy, seem to counteract this problem. They can provide an environmentally friendly way to regulate temperature without relying on active cooling systems. One of the simplest passive cooling technologies is shading. Actually, containers are shaded with additional roofing or camouflage nets. Disadvantages here are the additional material required and the assembly and disassembly when moving and during storms.

A relatively new technology for passive cooling is based on coatings. These have the advantage that no additional material has to be transported or assembled after the paint has been applied. Coatings containing e.g. ceramic or BaSO4-particles, which are already commercially available, enable slower heating and lower surface temperatures due to high reflection in the solar spectrum. Based on findings from Columbia

University, a Canadian startup developed a porous polymer layer that combines high reflection in the solar spectrum and high emission of thermal radiation (passive daytime radiative cooling - PDRC) [Mandal 2018]. Under ideal conditions, temperatures below ambient temperature should be achieved.

Beside coatings, latent heat storage plates containing phase change material (PCM) applied outside of e.g. containers prevent surfaces from heating by storing the heat. As long as the heat storage capacity is not exceeded the container surface, and also the volume of the container, does not heat up. PCM-boxes were already tested in a real-size experiment and showed a good behavior in reducing heat up [Sonnick 2020]. At least, spacer fabrics also can help cooling down surface due to an air flow induced by convection inside the fabrics. [Pires 2011]

All technologies have advantages and disadvantes regarding different points like cooling power at different weather scenarios, application, stability and the possibility of optical adaptation. Especially the assessment and the comparison of the cooling power of the different technology based on literature data is challenging. Therefore, all technologies are be applied on containers standing next to each other. Measuring the temperature inside and outside allows to evaluate the cooling performance of the different technologies. Further, the power of the air conditioning systems inside the containers is measured to investigate possible energy savings.

3 THEORETICAL BACKGROUND

3.1 Passive Cooling Technologies

3.1.1 Shading Systems

Passive cooling through shading is an effective method to protect buildings or containers from excessive heat, especially in warm climates. By strategically placing camouflage nets or roofing, direct sunlight exposure is reduced. This leads to decreasing heat absorption, a decelerated heat up and energy savings. The advantage of this technology lies in its simplicity. The disadvantage is, that additional material and good construction skills are required for applying safe and efficient shading structures. [Bhamare 2019, Kamal 2012]

3.1.2 Radiative Cooling

Radiative cooling can be achieved by applying coatings which contain thermal radiation emitters emitting heat in form of infrared radiation to lower the temperature of surfaces and reduces heating from solar radiation inside buildings or containers. Passive daytime radiative cooling is a specific application of passive radiative cooling and operates during daylight hours. PDRC coatings are based on materials which reflect sunlight and emit thermal radiation to cool down surfaces even when the sun is shining. By selectively reflecting sunlight while efficiently emitting heat, these materials achieve significant lower temperatures than traditional coatings. The surface temperature with PDRC coatings can even be lower than ambient temperature. PDRC coatings are based on different technologies like e.g. using BaSO4-pigments, different shaped ceramic particles or applying a porous polymer layer. This technology is most recommended for hot, dry climates with high global irradiation but also can be used in other climates. A disadvantage of these paintings lies in their limited colour range: with increasing darkness of the colour lower cooling power is available. [Bhamare 2019, Chen 2021, ECT 2007, Mandal 2018, Mandal 2020]

3.1.3 Phase Change Material

Phase change material-based latent heat storage plates absorb or release heat during their phase transition. Therefore, they are appropriate to store and release thermal energy. PCM, often based on parrafins or salts, are integrated into plates and absorp heat at their transition from solid to liquid and vice versa. Using PCM plates enables compact and effective storage of large amounts of thermal energy at relatively low costs. The disadvantage is the limited heat storage capacity. If the capacity is exceeded, the plates have to be reconditioned by cooling down (e.g. at night) for giving off the stored heat. [Oropeza-Perez 2018, Sonnick 2020]

3.1.4 Spacer Fabrics

Using spacer fabrics on surfaces allows the cooling of buildings or containers without relying on active cooling systems. In this technique, the spacer fabrics efficiently dissipate heat with an airflow caused by convection. [Pires 2011]

4 EXPERIMENTAL

For testing the passive cooling technologies in a real size scenario, ten 10 ft containers are equipped with the different technologies (Fig. 1). Two reference containers are coated with typical military coatings approved by TL 8010-0002 in RAL 6031-F9 bronce green and RAL 1039-F9 sand beige (C1 and C2). The containers C3 and C4 are equipped with the PDRC Coating PolyFrostTM by the canadian startup Chillskyn, where C3 is only coated on the roof. The coating Supertherm by SpiCoatings is applied on C5 and C6 is coated with Pleyers800® by Porviva. Latent heat storage plates with a phase transition temperature of 25°C are mounted on container C7 by MELT. The used spacer fabrics on Container C8 are from Müller Textil. Additional additive manufactured chimneys on the roof shall help to cool down the roof efficiently. On the last two containers, the shading was recreated using roofing (C9) and camouflage nets (C10). All container doors face south.

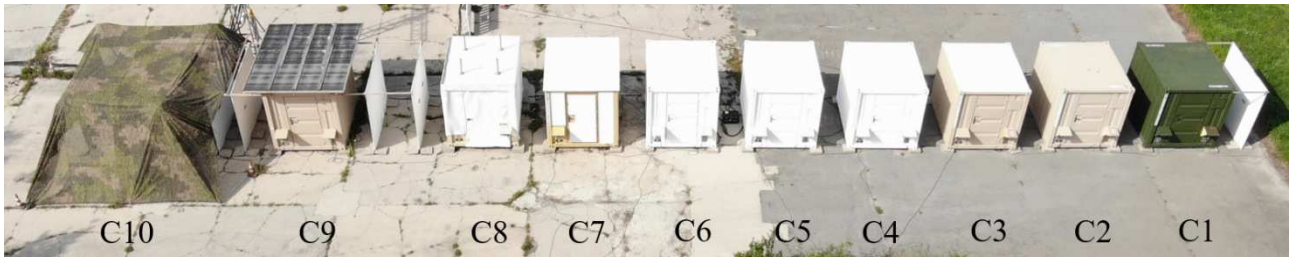

Fig. 1: Test setup for passive cooling technologies on 10 ft containers (from left to right: camouflage net, roofing, spacer fabrics, coating Pleyers800®, coating Supertherm, PDRC coating ChillSkyn, PDRC coating ChillSkyn roof only, reference sand beige, reference bronce green)

The temperature data is recorded with type K thermocouples and Pico TC-08 data loggers. Thermocouples are applied outside on the roof and on the door and inside on the roof, the door and in the middle of the containers. Further, Trotec BL 30 climate data logger are placed inside the containers. Thermal images of the containers are made with DJI Mavic 2 Enterprise drone equipped with a Mavic 2 Enterprise Dual thermal imaging camera und Mavic 2 Enterprise Dual vision camera.

The containers C2 to C10 contain air conditioning systems K3RNB9A from Gree. The power of the air conditioner is measured with the Sefram DAS 1400 portable recorder and the appropriate current clamps and adapters.

By using a weather station, the global radiation, rain, wind and temperature are recorded.

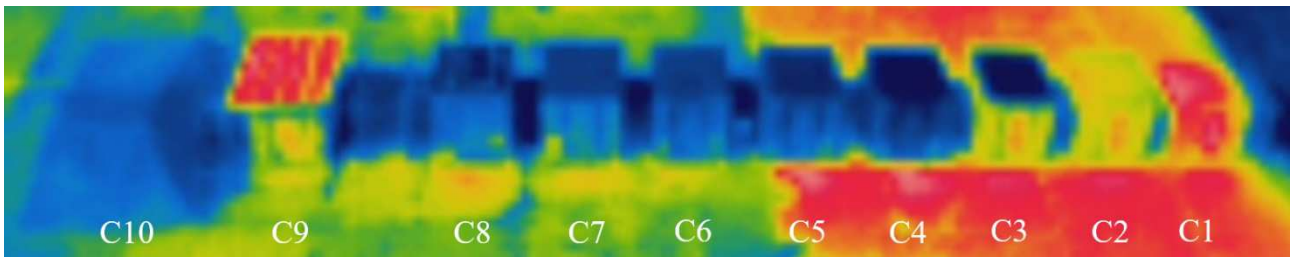

Fig. 2: Thermal image of the test setup for passive cooling technologies on 10 ft containers (from left to right: camouflage net, roofing, spacer fabrics, coating Pleyers800®, coating Supertherm, PDRC coating ChillSkyn, PDRC coating ChillSkyn roof only, reference sand beige, reference bronce green)

5 RESULTS

Thermal imaging is a good way to get a qualitative overall impression of the cooling behavior of the various technologies. Figure 2 shows a thermal image of all containers taken with a camera equipped drone. Cooler parts are shown in blue colour, hot parts appear in red colour (detailed assignment of colour to temperature is not available). All containers equipped with a passive cooling technology are blue coloured and show lower temperatures than the reference containers C1 and C2 with the exception of container C9, which has a roof

for shading the container. Also noticable are the containers C3 and C4 which have the coolest roofs showed by the deep blue colour. These containers are coated with the PDRC coating PolyfrostTM.

5.1 Temperature measurements

For getting quantitative informations about the cooling power of the different passive cooling technologies, temperature is measured inside and outside of the containers. Figure 3 shows exemplary for the day of 14th august 2023 the maximum temperatures inside and outside of the container. The maximum environmental temperature for that day was 33°C and there was no rain or clouds. Regarding the temperature outside, the container with the PDRC coating shows maximum surface temperatures lower or similar to the environmental temperature. Compared to the reference containers, there is a temperature difference of 23°C to the sand beige one, and even 32°C to the bronce green container. For the other passive cooling technologies, the surface temperature is also lower compared to the reference containers. the maximum surface temperature for all passive cooling technologies can be found at 42°C for the container with the spacer fabrics.

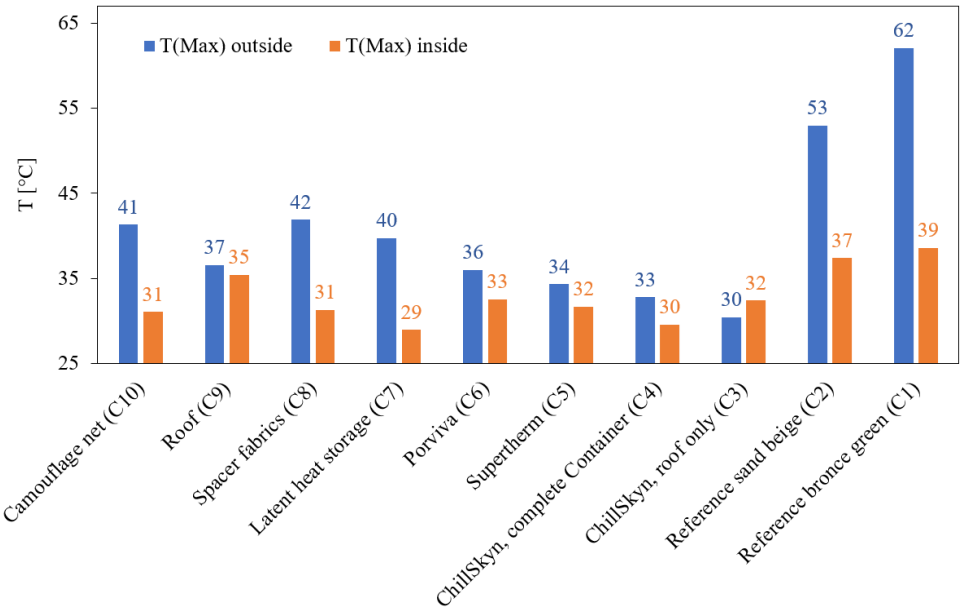

Figure 3: Exemplary maximum temperature for one day (14 August 2023) measured with PicoLog dataloggers outside the container on the roof (blue) and inside the container (orange)

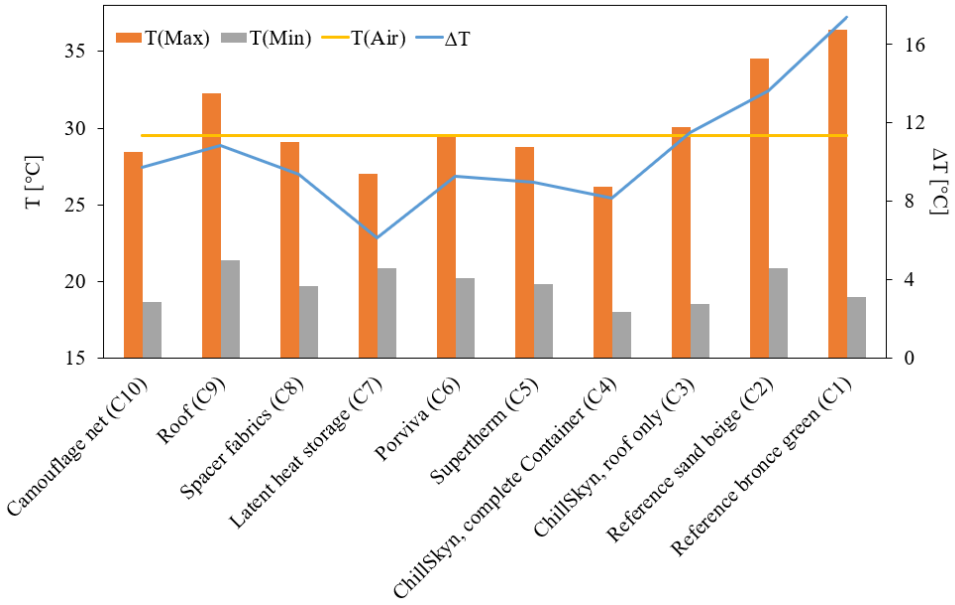

Figure 4: Average maximum and minimum temperature inside the containers measured with the Trotec dataloggers for week 32 and 33 as well as the difference of both temperatures and the temperature of the environment

The temperature inside the containers at 14th august 2023 is for all containers lower and lies between 29°C and 39°C. The maximum temperature inside is also measured in the reference containers. The lowest temperatures can be found at the container with the latent heat storage plates followed by the containers with the PDRC coating. For getting a more general assessment of the cooling power, the average maximum and minimum temperature inside the containers is determined for a time interval of two weeks (see Fig. 4). The difference of the maximum and minimum temperature is also showed as a parameter for temperature fluctuation during a day. By far, the latent heat storage plates and the PDRC coating show the lowest temperature inside the containers. The temperatures for the other passive cooling technologies lie just below or around the environmental temperature with exception of the container with the roofing. The reason for the heating of this containers can be the unshaded front (door area) of the container.

Regarding the temperature difference it is noticeable, that the container with the latent heat storage plates has an average temperature fluctuation during the day of only 6°C. Due to heat release during the night, there is a higher minimum temperature. This can influence the energy saving behavior negatively compared to the other technologies, but for storing material, which is sensitive to periodic temperature fluctuation, this can be the technology of choice.

5.2 Energy saving due to passive cooling technologies

For evaluating the possible energy savings by using different passive cooling technologies, air conditioning systems ran and the power was measured. Figure 5 shows the power for all containers needed in a time period of 2 days. The highest energy consumption can be seen for the reference container (C2) and the container with roofing (C9). The lowest energy consumption can be recognized at the container with the overall PDRC coating (C4) and the container with the spacer fabrics (C8). There is no final explanation yet why C8 performed that well at the power measurements but was unremarkable in the temperature measurements. One idea is, that due to rain, which occurs in the named time period, there was an additional cooling effects based on condensation, but this has to be verified in further investigations. Noticeable is, that the container with the camouflage net (C10) and the container with the Supertherm coating (C5) also show a low energy consumption. The higher consumptions of the latent heat storage plates can be explained by the heat release at night and the temperature of 23°C, which was applied on the air conditioners and lies below the phase transition temperature of 25°C.

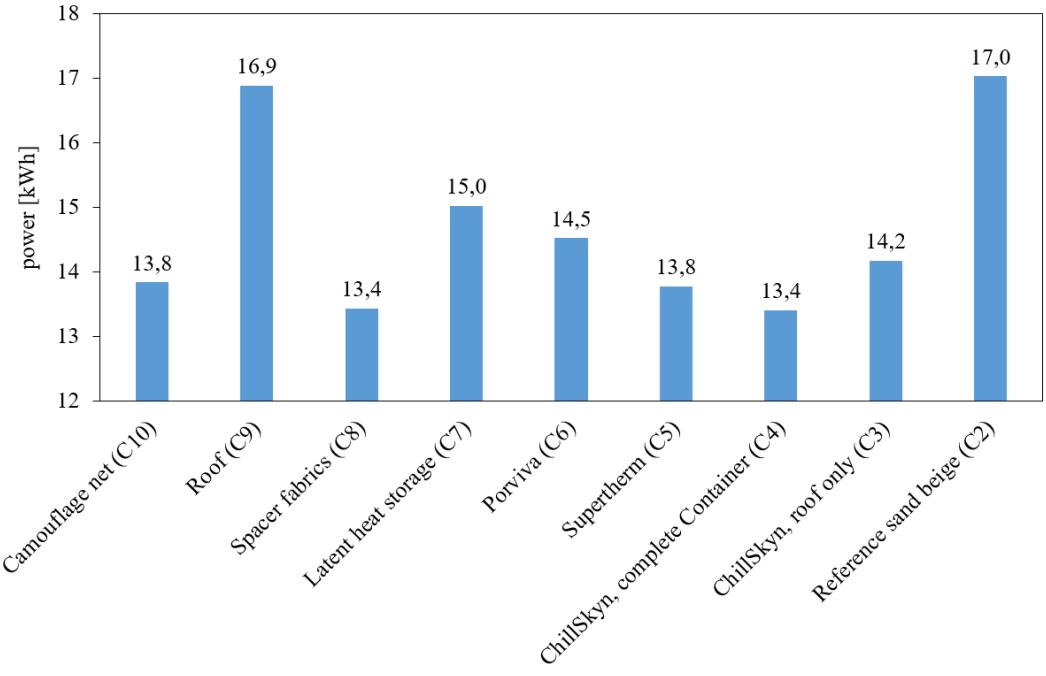

Figure 5: Power of the air conditioning systems running in the operating mode Auto for cooling down to 23°C measured from 22 to 24 August 2023

6 CONCLUSION

The investigations show, that with different passive cooling technologies a reduced heating of the containers can be achieved. An outstanding performance shows the PDRC coating with low surface temperature, low temperature inside the container and low energy consumption. Also the latent heat storage plates show a good cooling behavior inside the containers. Regarding military applications, the PCM plates have the advantage of the adaptility of the surface, where cooling coatings are limited due to decreasing performance with increasing darkness of the colour. Nonetheless, the coatings Supertherm and Pleyers800® show also a good cooling behaviour. The usage of spacer fabrics and camouflage nets can be used for minimizing heating of the containers but with the disadvantage of assembly and disassembly when moving the containers. Overall, passive cooling technologies should be considered as good solutions for reducing heating. The choice of the technology should be dependent on requirements of the application.

In further investigations, the influence of different weather scenarios on the different technologies should be taken more into account. Also aging and the performance of the technologies with contamination should be examined.

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