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The importance of urban green spaces in the development of smart cities

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In the era of modernization, urban green spaces (UGSs) are attracting increasing attention in smart city (SC) development. There is currently a paucity of UGSs, and their importance has become crucial in enhancing life expectancy and health. To meet people's demands, scientists are busy designing smart cities under flagship programs for urban transformation. UGSs are relevant in the analysis and investigation of improved lifestyles. The scarcity of UGSs can have many social and physical impacts. The presence of UGSs in smart cities is proposed to improve residents' lifestyles. Semi-structured interviews were conducted with residents, officials and government experts to inform the development of UGSs further. The result of the surveys analyzed using the MAXQDA software, which presents the importance of SC and the residents' satisfaction. The results show an urgent requirement for larger UGSs to enhance the security and economic opportunities within urban environments. The deployment of UGSs is particularly relevant to fully enhancing residents' lifestyles and health. The present research aligned with the World Health Organization (WHO) standards to identify the scope of UGS initiatives in different parts of the city of Graz, Austria, and recommendations for improving the quality of future UGS planning is provided. The proposed research results conclude that UGS is a valid alternative to enhance air quality, with measurable and substantial air pollution changes even in space-constrained sites.

KEYWORDS

urban green spaces, sustainable and resilient urbanisation, green infrastructure, climate change, smart cities, urban environmental sustainability

1 Introduction

Much of the population has moved toward cities in recent decades. In Europe and North America, currently, nearly two-thirds of the population resides in cities, and it is predicted that, by 2050, two-thirds of the world's population will live in cities (Appleyard, 2007; Arnstein, 2011; Chitewere et al., 2017; Pauleit et al., 2019; Bounoua et al., 2020). Urbanization is certainly one of the greatest changes that humanity has experienced. The city of Graz in Austria, with an approximate population of 330,000 is rapidly expanding. Its infrastructure and housing must mirror this trend, and significant building activity is underway in many parts of the city. Urban planners and developers aim to build a city that serves the residents, is interesting for visitors and maintains its status. Residents' experience is particularly important, as they live in the city environment and contribute to its development, whereas tourists leave the city after a certain time (Zimmer, 2010; Xu et al., 2018; Cortinovis et al., 2019). In addition to expanding housing options and

infrastructure, the residents' health, quality of life, and environmental aesthetics are important considerations when designing cities.

Healthy and happy city dwellers are at the core of city design. Therefore, it is much important in order to take steps to improve the health of local dwellers. As social beings, people need contact with others and opportunities for exchange and amicable interactions (Moore, 2007; Hunter et al., 2014; Jänicke et al., 2015; Hoelscher et al., 2016; Wang et al., 2023). On the one hand, modern life limits these basic human needs. The city residents are now becoming more isolated and spending noisy and hectic lives. The tendency towards private living measures, jobs in isolated offices and the increasing fame of coaches as the main means of conveyance contribute to this segregation. Phenomena such as high traffic load, noise, deprived air quality, the temperature rises, and violence are more public in cities than in rural areas (Jennings et al., 2012; Kallio et al., 2016; Besir and Cuce, 2018; Antón et al., 2022; Rehman et al., 2022; Rehman and Holy, 2022). On the other hand, cities deal with many buildings that brand life easier than life in the countryside—the reason of cities expansion.

Jobs in dense offices, infrastructure, and freedom activities are in high demand. Therefore, cities that facilitate first-class lifestyles undergo high annual resident development, attracting more competent workers, students, companies and tourists. Public green spaces play a significant role in city design, counteracting its isolating aspects. An important form of public space in any urban environment is the green space, and urban densification risks the limiting of such spaces (Kaplan, 1995; Braveman, 2003; Leminen et al., 2012; Lottrup et al., 2015; Rudnicka et al., 2020). Green spaces are essential components of a livable city because they provide healthier environments and diverse advantages for urban residents. According to numerous studies, people who live near usable greenery are happier and healthier than those who do not (Lyytimäki and Sipilä, 2009; Wolch et al., 2014; Bounoua et al., 2020; Mudau et al., 2020), as such spaces are the flawless atmosphere in which to take a break from the stress of everyday life.

The greening of cities is an important strategy in the context of ongoing climate change, and living sustainability is increasingly part of modern lifestyles (Hwang et al., 2020; Van et al., 2020; Hou and Wu, 2021; Cai et al., 2023). In Graz, the topic of greenery and vegetation has risen to prominence through the controversy surrounding the Mur power plant, Augarten Bay and the poor air quality in recent years. Demonstrations and other events have increased awareness about these issues, attracting more interest as young residents take to the streets to fight for a better environment. The myriad benefits of urban green space are relevant to all these situations. Although Graz has a comparatively great density of green spaces related to other European cities, such spaces are distributed unevenly. Some of the remote districts and communities have large green belts, and the more prosperous inner neighborhoods, with large number of green spaces due to the presence of the densely vegetated inner courtyards of the Wilhelminian-style buildings (Maas, 2006; Besir and Cuce, 2018; Sugiyama et al., 2018). To focus of the proposed research work is the urban development and the investigation of few research questions. The main objective of the proposed work is to examine these research questions. The research work is contributed in the form of these two questions, which are given as;

1. How do residents exploit and evaluate the urban green spaces (UGS) in Graz and in the city oasis of the green laboratory (GL)?
2. What is the significant role of the GL in analyzing the UGS and how important the UGS in enhancing the living style (i.e., improving the quality of life) in the development of smart city (SC)?

Herein, we consider how these questions affect the quality of life and health concerning the literature, as well as how green space is anchored in the instruments of the city and the social sustainability of green spaces. We also examine some selected controversies concerning the city's greenness using a methodological approach centred around semi-structured interviews and accounting for the selection of the investigation area. The empirical part of this work describes the investigation area—the Graz SC—and its construction sites and expansion areas, in which the interviews were also conducted. We also discuss the company StadtLABOR and its project of the green laboratory, in which this research was conducted. Herein, we report the results of citizen and expert interviews, interpreted in the Results section. Furthermore, we present recommendations for the construction of high-quality green spaces. In the Conclusion section, we answer the two research questions above, reflecting on the methodology and outlining possible directions for future research.

2 Background

The potential for the development and promotion of green space is considerable. Many users spend time in parks standing, sitting or lying down. The further development of green axes along roads or bodies of water offers considerable potential to encourage activity and positively contribute to the climate and positive image development (Chen et al., 2023; Grigoletto et al., 2023).

Nonetheless, the SC concept has received considerable criticism from citizens. Such construction projects do not arise in the short term but take over 10 years or more, with unavoidable periods during which the affected areas are unsightly and lacking in green space. Ten years is not a long time for a city, but for a resident living near a construction site for several years, health and wellbeing can be negatively impacted. Therefore, astute measures for the temporary use of wasteland are of particular value. Graz has offered subsidies for community gardens, roof and facade greening and the planting of urban trees, since April 2020, to increase the proportion of green space and create awareness among residents. Funding is available for the purchase or lease and the construction of green spaces, as well as for the materials needed for cultivating a green space. Eligible urban trees must be planted outside the Graz green belt on private property. In addition, there is a scheme under which a tree is made available for planting for each newborn baby in the city (Farkas et al., 2023; Honey-Rosés and Zapata, 2023).

Every 5 years, Graz conducts a large-scale study on the quality of life of the city's residents called "The City of My Life—Quality of Life Survey of the city of Graz". This survey was most recently conducted in 2021. In addition to collecting ethnographic data, citizens were asked about 11 indicator groups: Local supply, health and service facilities, cost of living, housing situation, environmental quality, recreational value, security, work situation, traffic, education and

childcare. The respondents were classified according to their residential district, with each district further subdivided, resulting in the creation of 46 survey zones.

2.1 Urban political ecology

Political ecology is the study of the effects of the political environment on the human and physical environment, focusing on political structures and power constellations, and offers a critical perspective on the interrelationship between nature and society. This discipline criticizes monocausal attempts to explain transformation processes or environmental crises. The principles of political ecology claim that a crisis does not result solely from natural or ecological processes (e.g., nature deterministic processes) but also from social processes. According to political ecology, environmental crises are also always strongly politically influenced (Zimmer, 2010). In urban political ecology (UPE), it is noted that nature and society in cities may often be erroneously perceived as separate. In many research methodologies, a city is not seen as something natural but as a counterpart to nature (Moore, 2007; Hoelscher et al., 2016; Xu et al., 2018; Cortinovis et al., 2019). UPE considers all urban processes interconnected with nature and culture or society; i.e., it considers them a hybrid system. The value of community is often rated higher than nature's; however, these systems cannot be easily unravelled.

The social and natural environments in cities should be unified to guarantee the survival of both systems. Whereas towns require resources for consumption, a considerable waste reduction can provide more space for natural regeneration and development, conferring advantages for people and the environment. The concept of hybridity denies the justification for a city's lack of natural spaces.

According to UPE, nature is not external to be understood as independent of human action and social structures. In the past, many natural disciplines have been ascribed a passive role—the context in which social action takes place—considering nature a resource inviting political action. However, cities are sociophysical constructs demonstrating the relevant qualities of this hybridity. The urban environment is often referred to in the literature as a cyborg: natural, social, technical and cultural. Transformational processes, therefore, include all these aspects (Nesbitt et al., 2018; Schram-Bijkerk et al., 2018).

UPE critically examines the social causes of environmental problems in cities, as re-source scarcity can be an example of an ecological crisis. Access to and control over resources are often not fairly distributed, not due to environmental deficiencies such as a lack of natural resources or social processes, but as an expression of political power. Resource scarcity is therefore conceived as a result of the (politically influenced) unequal distribution of resources or of, overproduction or consumption patterns, or a combination thereof (Maas, 2006; Sugiyama et al., 2018).

UPE aims to determine who benefits from changes and who loses, emphasizing the interactions between ecological, social and economic processes on several scales. The principles of UPE advocate for sustainability and democracy through a more even and inclusive distribution of social power structures. Therefore, a proper socioecological perspective on cities must always elucidate

who wins and who pays and must disclose and question complex power constellations. With this background knowledge, the present study argues for more nature in the city in whatever form is most appropriate.

What makes cities worth living in and the importance of public spaces has been explored and answered from various perspectives over the centuries. Another interesting consideration is how the value of public spaces has been perceived differently over time, as well as the influence of social trends on this perception. Public space is understood not only as public squares or parks but also as streets, markets, playgrounds, community gardens, waterfront promenades and urban forests (Manzoor et al., 2019).

2.2 Historical development of public and green space

Public spaces in European cities have undergone several changes in recent centuries. In the middle ages, cities were dirty, chaotic and noisy. Modern cities have their origins in the industrial age. Towards the end of the 18th century, the advent of mass production contributed significantly to the emergence of many industrial companies that created jobs in cities, resulting in an increasing number of streaming into urban spaces. Slum-like working-class neighbourhoods with high crime rates emerged, and many workers lived in tenements or barracks. Due to the high density of people and the poor hygiene standards, many diseases and epidemics (e.g., cholera) emerged. Urban supply and sewage systems, waste and gas supplies, and paved roads were gradually introduced, including a few developments designed to address sociopolitical grievances and combat diseases (Sasatani et al., 2015; Liu et al., 2022; Zhao et al., 2022).

To fight against the hygienic deficits and as a reaction to the lack of recreation, parks were created on a grand scale in the 19th century for recreational purposes. The aim was to provide green areas and street furniture for citizens. Interestingly, the use of the Graz city park has changed. In the past, walking in the meadow was forbidden. Today, people play, picnic and practice sports in the meadows. UGSSs have continued to serve as recreational spaces that promote wellbeing, even if this was not explicitly the dominant ideology (Jennings et al., 2012; Jänicke et al., 2015; Kallio et al., 2016; Besir and Cuçe, 2018; Antón et al., 2022).

In the 20th century, public life was often left out of planning ideologies. Common spaces, such as city or local squares, were considered necessary and functional; however, there were exceptions. Several residential cities were built in concentric arrangements around core city administrative functions. Therefore, the individual uses of gardens in the original plans were separated from the rest of the city plans. In the 21st century, there is a renewed emphasis on mixed functions (Rehman et al., 2022; Rehman and Holy, 2022).

The years after the Second World War were marked by reconstruction and humanitarian living with abundant greenery was neglected during this time, reflecting the alienation of nature. Numerous trees were cut down in favour of building projects, individually centred traffic developments, and small watercourses were channelled and built over. Between 1950 and 1970, the car-friendly city became the dominant model, with the construction of

density being abandoned. This process of suburbanization in times of economic prosperity came about primarily through the advent of the personal automobile, the desire for more privacy and greenery, and high housing prices in city centers. Large urban settlements were often left to the less affluent classes (Kaplan, 1995; Braveman, 2003; Leminen et al., 2012; Lottrup et al., 2015).

Residents living on streets with only light traffic had more acquaintances within the neighbourhood. The onset of deindustrialization in the 1970s led to many vacancies in industrial cities and regions. Greening buildings, for example, have been around since the 1980s and have become topical again. Green roofs and facades were present in the 19th century but became more popular later. In the 1970s, an environmental movement emerged, intending to protect cities in Germany.

Today, living in cities is popular. The number and variety of jobs and improved leisure opportunities have allowed cities to flourish again. Such urbanization is desired and planned—in contrast to the period of industrialization. Therefore, public lounges, green spaces and leisure activities have been reunited and enjoy an elevated status in city and urban planning. The positive connection between urban greenery and the health of users of public spaces has also been confirmed. Easily accessible amenities contribute considerably to the modern quality of life. The active public life leads to a healthy, socially inter-active and thriving city. This understanding can also be explained by changing lifestyles, habits and, consequently, the changing needs of city dwellers, who influence the value and use of public spaces through their actions.

The change from predominantly manual, standing employment to predominantly seated office work has meant that people move much less than they used to. The predominance of the automobile as the main means of transportation, the development of escalators and elevators, and changing eating habits have also contributed to this phenomenon. In recent decades, this trend has led to diseases and a higher proportion of obese people. Therefore, conscious physical activity must compensate for the lack of daily exercise. Willpower and stamina are required for sports, gymnastics, jogging and home training. However, people often lack time, money or energy to engage in such activities several times a week. Health policies are therefore called upon to take measures to integrate exercise into everyday life. Infrastructural routes to work must be designed to be appealing so that more people can walk or cycle. Information campaigns should also be conducted to inform citizens about the benefits and opportunities of physical activity. Healthy and happy people are known to be more productive than unhappy, sedentary people. Creating spaces for leisure and exercise is the most effective way to achieve a human-friendly and environmentally-friendly city. Examples of such measures include widening sidewalks, the construction of easily passable coverings for cycle paths, open road crossings, street furniture, shady trees, sufficient lighting and a lack of spatial separation walls. Attractive and safe places, rest stops, cafés and parks should be offered to citizens.

2.3 Urban green as public space

Urban greenery is a defining element of cities and an important part of building culture. There is currently a consensus that green space improves the quality of life and increases the attractiveness of a

city. Green space informs the design of large, medium-sized and small towns. It serves a variety of functions for a sustainable city. Integrated and sustainable urban development aims to strengthen UGSs and provide a range of ecosystem services (ES) so that people can utilize their benefits.

2.4 Climate effectiveness of green spaces

All vegetation types serve many climate-related functions, representing services offered by green space ecosystems. Ecosystem services are the contributions of ecosystems to climate and human wellbeing. Green space can increase air quality and humidity. Through the photosynthesis of foliage and rooting, plants absorb CO₂ from the air and remove particulate matter, exhaust gases and nitrogen dioxide (NO₂) through the combination of the evaporation of water from land and water surfaces (evaporation) and the discharge of water through leaf openings (transpiration).

Another contribution of green spaces is that rainwater seeps into unsealed areas, which is important when weather conditions change. The denser the proportion of vegetation, the more rainwater can be absorbed, increasing evapotranspiration. Green spaces also improve water quality by removing pollutants and filtering heavy metals. Evapotranspiration can be conceived of as a passive cooling strategy, reducing cooling demand in buildings (Besir and Cuce, 2018), reducing the speed with which wind impacts building facades and filtering out pollutants. The temperature differences between green and non-green walls can reach double digits depending on the thickness of the substrate and the vegetation density, reducing the overall energy consumption of a building. Green spaces can also influence and somewhat dampen noise generation (Hunter et al., 2014; Jänicke et al., 2015; Hoelscher et al., 2016; Besir and Cuce, 2018).

2.4.1 Climate planning

There is a need for green and open spaces, and it is pertinent to promote climate-adapted green infrastructure in inner-city areas. New green spaces should be created, and existing open spaces should be preserved and networked with suburban areas. A large-scale expansion of green infrastructure is possible either on fallow land or in the course of new construction projects. Existing compact settlement structures should be maintained; however, the expansion of green space should not be endangered. Therefore, incorporating several small-scale green spaces into the housing stock is important.

Green areas with diverse vegetation structures (different plant species and varying altitude levels) provide the greatest cooling effects. In addition, large open spaces promote small-scale greening measures (facades, inner courtyards and rows of trees), especially given that such spaces can usually be implemented with little effort. Green and open spaces should be made available as parts of rainwater retention systems. During dry periods, such open spaces can stabilize the water balance and reduce the risk of flooding during heavy rain events. In this way, surface water can be drained off in a targeted manner. The selection and location of plants should increasingly consider that they may need to cope with changing temperatures. Equipment elements such as benches should be positioned according to weather conditions. For example, more



covered seating is required in wetter areas than in mostly sunny areas. Shaded seating is also important. Road surfaces can be finished with gravel or crushed stone instead of asphalt so rainwater can escape and seep away (Kaplan, 1995; Braveman, 2003; Leminen et al., 2012). The protection and expansion of green spaces are indirectly anchored in all the above mentioned principles.

2.4.2 Selected types of green space

Green infrastructure includes large parks, playgrounds and open meadows. However, many other types of green space can contribute to mitigating the effects of the urban concrete jungle, including roof and facade greening, individual trees or tree rings, road islands (front) gardens, forest areas, sports fields, green tram tracks, roadside greenery, urban gardening, parklets, agricultural land, urban recreation areas and green cemetery spaces.

2.4.2.1 Roof and facade greening

According to (Besir and Cuce, 2018), buildings account for around 40% of all energy consumption in Europe, and 36% of greenhouse gases come from building emissions. Therefore, greening buildings is one of the most sustainable methods for counteracting the heat stress of cities. Mainly industrial and commercial buildings have considerable potential for greening (Hoelscher et al., 2016). An example is the roofs of large shopping centers. Such ecological measures serve not only greening purposes but also a contribution to the energetic optimization of the building (insulation and shading), the possibility for rainwater management, the extension of habitats for animals and insects and the improvement of indoor air quality (Cai et al., 2023). Green surfaces can reduce the heating requirements of buildings by 10%–30%. In summer, the temperature difference between buildings with conventional and green roofs is up to 12°C (Besir and Cuce, 2018).

With the advent of the flat roof in the 20th century, the affinity for green roofs also in-creased. However, whether a roof is suitable for greening depends on the building statistics. The structure of a green roof consists of several components: drainage material to retain moisture, protective and filter layers, a root barrier, the

substrate serving as a growth medium and vegetation (see Figure 1). A distinction is made between extensive and intensive green roofs. Less demanding and self-sustaining plants such as mosses, grasses or herbs are used for extensive greening of roofs. No human use is intended on such roofs, with greening serving as a protective layer for the roof to mitigate the effects of the climate. The floor structure is 60–200 mm, so it can be applied to more roofs than intensive greening.

Around 80% of green roofs in Germany are now extensively green (Sasatani et al., 2015). Intensive roof greening can be carried out using plants of all kinds. Larger trees can grow on intensive green roofs, and paths can also be created so people can use the roof as a park. This type of green roof requires a more complex soil construction (150–400 mm) and considerable horticultural care and is therefore associated with significantly greater financial effort (Besir and Cuce, 2018).

Figure 2 shows a green facade wall at the GL in Graz, for which the watering is automatic and digitally controlled. Fleece is utilized as the substrate, and plants are inserted in the holes—in this case, lettuce, tomatoes and peppers. This type of facade greening needs detached watering approaches and more care, which is why this is the more expensive option with a larger selection of plants (Hoelscher et al., 2016). Iron bars were attached only as a climbing aid, with the red balls at the ends of the bars serving as protection against injuries. However, they make the wall look even more interesting and colorful. Green walls can also be installed indoors and can be beneficial for health and affect the mood of building occupants (Hoelscher et al., 2016).

2.4.2.2 Green tram tracks and Urban gardening

Urban gardening is a special form of UGS wherein local, organic food is grown by citizens. Such spaces allow participants to engage in physical activity and spend time in nature, reducing stress and increasing health benefits. Urban gardening can be implemented on the ground or in troughs, making such spaces unsealed areas that can cool the climate, retain rainwater and improve soil quality. The social component is especially important in urban gardening. By gardening with fellow human beings, participants can learn from each other and create something together. Therefore, urban gardening provides multiple advantages and can contribute to the goal of a socially sustainable city (Schram-Bijkerk et al., 2018).

The initiators of urban gardening projects are mostly citizens who receive support from local political institutions. Such projects are often created in areas with a low market value, such as fallow areas or areas where construction will occur in the coming years. Thus, the projects are not always permanent facilities (Schram-Bijkerk et al., 2018). Figure 3 shows the community garden at Donaukanal in Vienna, which had 35 members in 2020. In this case, the area was provided free of charge.

2.5 Green and pollution-free smart city

In this section, we aim to highlight the importance of green spaces and contribute to the gaps in the relevant literature, considering the different aspects of green spaces in cities. From planning to evaluating the functions and opportunities to help shape green spaces, the findings provided herein provide a basic



FIGURE 2
Façade greening in the GL.

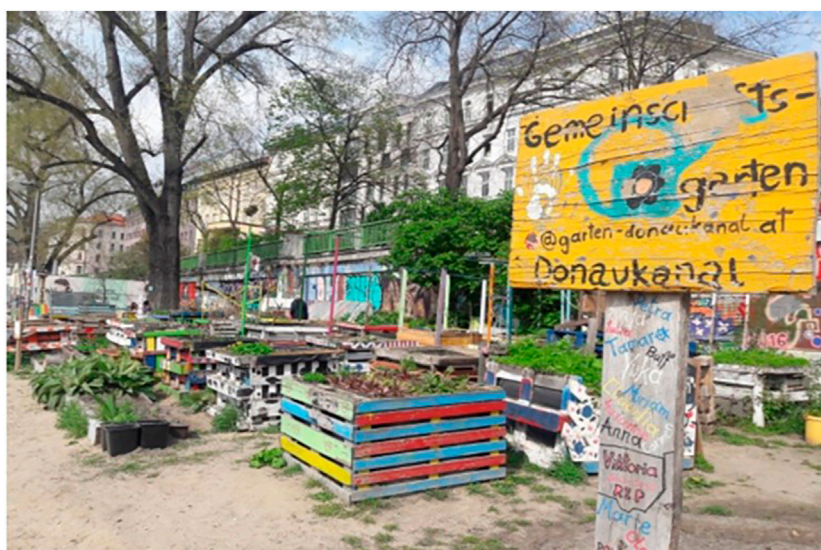


FIGURE 3
Danube Canal community garden, Vienna.

connection to the empirical investigation of the proposed work. The concept of a smart city is outlined in [Figure 4](#).

2.5.1 Health-promoting properties of Urban greenery

In addition to numerous health-damaging burdens, cities also have many health-promoting resources that contribute to mental

and physical health and social wellbeing. These resources include, among other things, a high density of health-related facilities such as sports clubs, doctors and hospitals, providing, for example, social support for families and neighbourhoods, a strong neighbourhood identity and free urban green spaces. The focus on the greening of cities has been particularly strong since the turn of the millennium and has now become a key practice for many municipalities.

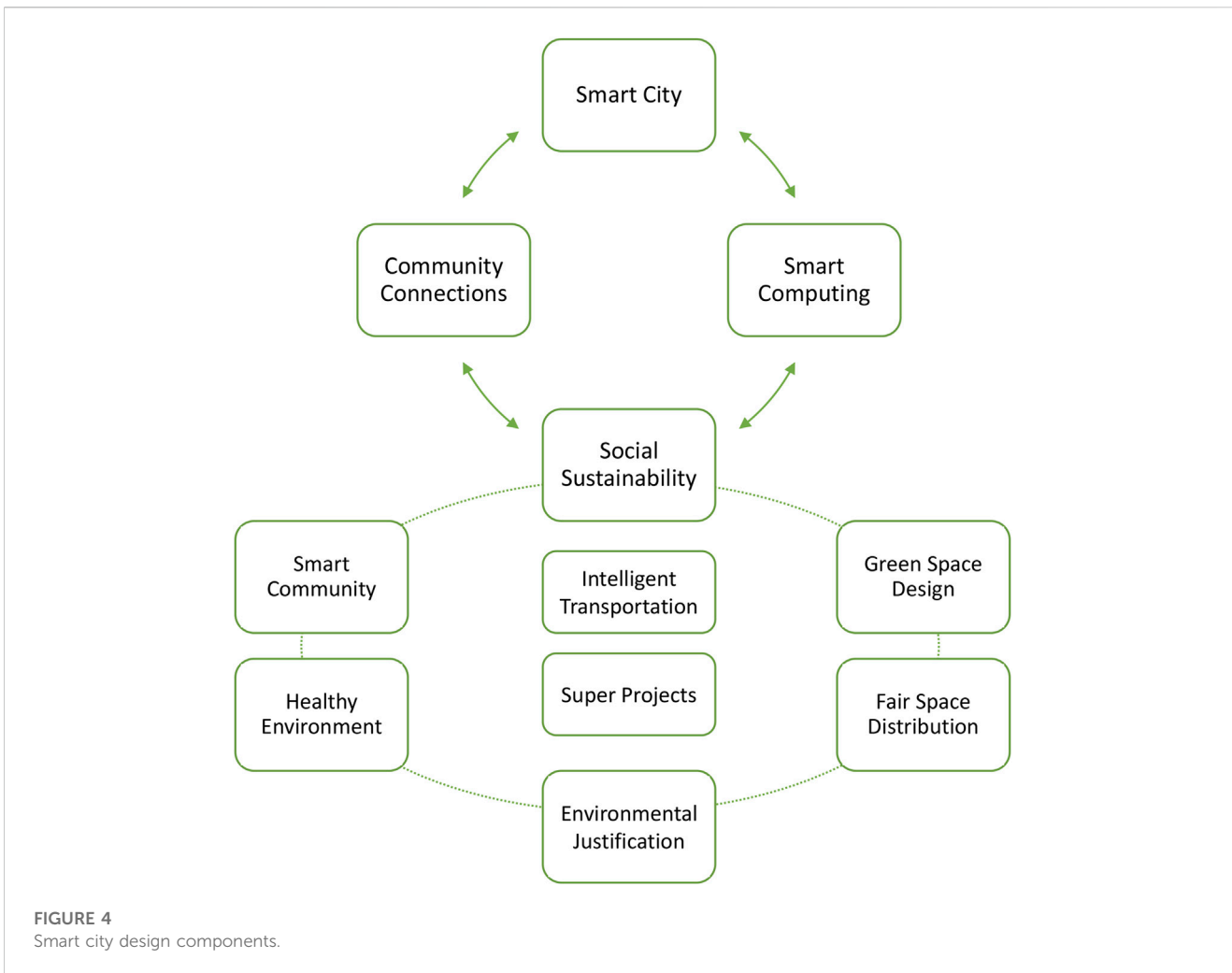


FIGURE 4
Smart city design components.

The range of urban green and recreational areas significantly impacts city dwellers’ quality of life and health, in addition to the previously described climatological effects. Green infrastructure contributes to the city’s experience of nature, recreation and aesthetics. Regular physical activity can make one physically fit and improve one’s mental health. Green spaces encourage walking or cycling, thereby contributing to a reduction in CO emissions. Green spaces also encourage productive labour by stimulating mental vitality by promoting active recreation, and alleviating the stress of everyday life.

2.5.1.1 Mental wellbeing

People prefer open, natural spaces and interaction with the elements. Urban green spaces can allow city dwellers to come into contact with plants and re-treat to such places, which can counteract loneliness. Green spaces can offer peace and tranquillity. People who live near a park are less likely to suffer from stress than those who do not (Zhao et al., 2022; Cai et al., 2023). Numerous studies have dealt with the connection between the mental health of individuals, people and companies and the frequency and type of use of green spaces and recreational facilities. The experience of landscapes can reduce stress, increase attention and concentration, and prevent anxiety and depression. Greening

systems significantly impact residents’ health and a city’s aesthetics and real estate prices (Besir and Cuce, 2018).

Such spaces divide noise in cities into external and internal noise. External noise is caused by traffic, other people or machines. People constantly exposed to loud noises are likelier to suffer from high blood pressure, negative moods and stress. Greening systems installed outside and inside can counteract such effects (Besir and Cuce, 2018).

2.5.1.2 Physical wellbeing

The physical wellbeing and health of citizens are essential factors in a livable city. Chronic conditions such as heart disease, cancer, diabetes and respiratory diseases are be-coming increasingly common, straining healthcare systems, with a considerable impact on the quality of life of those affected. Physical inactivity contributes to many of these dis-eases and should therefore be reduced. Cities can address these issues through targeted measures, thereby improving the general health of city dwellers. As recently as 30 years ago, a frequently cited study dealt with the recovery of people with restricted mobility who had recently undergone surgery for gallbladder removal. Patients with a green view from their hospital window recovered faster than those with a view of a brick wall. Patients with a green view stayed in the hospital for a shorter period and took fewer painkillers. Later, in a large-scale

study of around 250,000 participants, [Maas \(2006\)](#) found that the proximity of green space positively impacts people's health. In particular, green infra-structure positively impacts socioeconomically weaker groups where green space is much more intensively used.

Young and healthy people are often more active in parks and participate in more social activities than older or unhealthy people. Connections have been found between green spaces near residential areas and the reduction of obesity in children and the increased mobility of older people. [Hoelscher et al. \(2016\)](#) reported that human health is markedly affected by heat stress in cities. Increased mortality in people over 65 has been found with a small increase in average daily temperature, and high temperatures can result in deteriorated sleep quality among city dwellers.

2.5.1.3 Social wellbeing

As places that are theoretically freely accessible to everyone, public green spaces can also positively affect the social wellbeing of city dwellers and neighbourly relations. Such spaces serve as meeting places for people of different backgrounds, ages and sexes. The facilities located and offered in parks, such as cafés, sports facilities, consumption-free places and activity spaces, are important sociospatial systems. The educational aspect also plays an important role in urban greenery. Practice-oriented actions can impart knowledge about local ecosystems or the variability of the local climate, resulting in a better understanding of the balance of ecosystems and the relationship between one's actions and the ecosystem.

2.5.2 Green space design

An essential task of green space is to put human needs in the foreground. The more appealing or aesthetic the green space, the more often they are used. An area that is easily accessible, functional and aesthetically pleasing is socially successful, can promote social diversity so that no social group is excluded, and easily attract visitors. The needs of residents are met by green areas, which provide comfort and encourage relaxation, activity, exploration and fun. The criteria for successful green spaces include the number of square meters per resident and the fixed walking distances to or in the green space ([Zimmer, 2010](#); [Chitewere et al., 2017](#); [Pauleit et al., 2019](#); [Bounoua et al., 2020](#)).

Green spaces that do not yet have a fixed use or are still fallow land can be designed individually according to the needs of the residents. Such areas do not have to be designed as typical green spaces with lawns, benches and play equipment. Countless green space designs can be considered, with features such as urban gardening, insect hotels, beehives, public viewing areas, areas for barbecue events, food festivals, lectures, do-it-yourself workshops, exchange markets, fitness equipment and educational projects, among others, so that nature can be experienced with all the senses.

The approaches to the design of green space have constantly changed over the decades. Municipalities often set guidelines for the successful design of urban green spaces. However, these are often taken as a checklist to be worked through, which should not be the case. Each area has unique characteristics, making it conducive to particular design options for high-quality and

attractive spaces for people and nature. The successful design of green spaces should involve comprehensive research and community consultation.

2.5.3 Fair distribution of green space in the city

Inner-city green space also fulfills an important sociopolitical function. However, it is rarely evenly distributed across the city. What are the causes of unequal distribution and underused green space? Who has access to the affected green space, and when? In theory, in today's democratic societies, the public realm should be open and accessible to all citizens at all times. However, formal and informal codes of conduct and processes lead to *de facto* exclusion and discrimination. In the last 2 decades, social sustainability and, more precisely, unequal access to green space have been problems associated with environmental justice that have found their way into the public debate.

2.5.3.1 Social sustainability

A socially sustainable city is a space where all members of society are respected, and their integration, participation and equal access to public resources and services are guaranteed. Opportunities to contribute to social sustainability also consider these aspects, although they are not always fulfilled. Equal access to green spaces can be achieved by restricting socially exclusive processes. Therefore, public green spaces should be designed and maintained to optimize their functions and include as many members of society as possible ([Jänicke et al., 2015](#); [Hoelscher et al., 2016](#)).

Different patterns can be identified depending on the type of use—some parks tend to be more frequented by men, whereas others cater more to women. Studies have shown that women prefer to be in sheltered areas and engage in more communicative activities, whereas men use action-oriented spaces and occupy more space. In addition to gender, other factors such as ethnicity, age and socioeconomic status influence space appropriation. However, how residents use an area depends heavily on their personal preferences, experiences and current life situations.

2.5.3.2 Environmental justice

Large areas of greenery often characterize wealthier districts. In contrast, neighbourhoods with a predominantly low socioeconomic demographic have fewer or poorly preserved green spaces ([Jennings et al., 2012](#)). This phenomenon can be attributed to various causes, which are usually historical, e.g., the park design philosophy, the evolution of land ownership over time, the history of leisure and recreation and the varying class ratios ([Wolch et al., 2014](#)). Even today, access to green spaces often varies according to income, ethnicity, age, gender and physical or other impairments and is difficult to measure. Green spaces serve as a place of relaxation and social interaction, particularly for individuals from lower social classes. For people with low mobility or sparse monetary resources, urban green spaces provide free recreation and leisure infrastructure. Socially weaker individuals are more often at the mercy of limited financial means, poor education or a low social status. According to previous studies, such individuals frequently live on busy roads or near industrial plants because it is cheaper, in addition to living in smaller homes and apartments.

Urban political ecology also deals with questions of environmental justice. According to UPE, green spaces and their

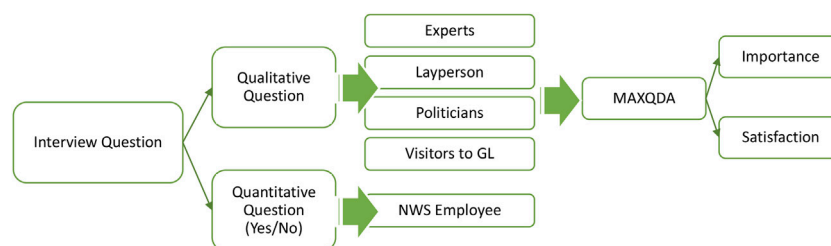


FIGURE 5
Qualitative and quantitative analysis procedure.

surrounding neighbourhoods are associated with capitalistic motives and a striving for growth, which come with the destruction of space and public goods. UPE conceptualizes green spaces as places where a struggle occurs concerning goods and services. Through the lens of UPE, power structures and inequalities can be un-covered and investigated concerning social and cultural norms in green spaces (Nesbitt et al., 2018).

2.5.3.3 Green gentrification

The creation of new green spaces can lead to a paradox. On the one hand, new green spaces can and should improve the lives of residents, the attractiveness and environmental quality of the district and citizens' health. On the other hand, developing green spaces can drive up property and rental prices, leading to gentrification. Land prices can make rents too expensive for the original residents of an area so that they must move to another part of the city with worse conditions. Such phenomena can occur even when the intention is to reduce inequality (Wolch et al., 2014). To prevent such outcomes, care must be taken to compensate the existing residents, e.g., in social housing. New green spaces can further exacerbate inequalities and increase the gap between the rich and the poor.

2.5.4 Green space controversies

Despite the numerous benefits for city dwellers, green spaces can also be associated with certain problems and controversies. Some issues related to green space development have been discussed earlier in this paper, such as the unsatisfactory supply of urban regions with green spaces, the unequal distribution of green spaces across the city, a lack of security, a lack of multifunctional spaces, conflicts of use, economic speculation on proper-ties near parks and the lack of stakeholder engagement.

Parks can serve as meeting places and centers of communities when they are well-placed and established. Green spaces placed in well-mixed, heterogeneous neighbor-hoods are more likely to be used at various times. However, green spaces can also negatively affect neighbourhoods if poorly placed, e.g., at the end of a district with little activity or in homogeneous neighbourhoods. In such cases, green spaces can also at-tract criminal activities at off-peak times. Most inner-city parking areas are too small to form such a green wall, and strong segregation of neighbourhoods is not pronounced in the form of green spaces.

3 Materials and methods

A quantitative and qualitative analysis is conducted to assess the implementation of UGS. The implementation plan is shown in Figure 5. 650 to 700 meetings were steered, of which 550 answers were documented. Attention was taken to contain a huge variety of questions from numerous people. The constraint was that the person who stayed the GL at least once had existed or functioned in the neighbourhood. The optimal of defendants took place on numerous paths instead. Residents were asked for interviews by appearing events in the GL. The visitors to the GL addressed who were willing to be interviewed. The Natur Werk Stadt (NWS) employees were present anyway and acquired the time to discuss. The interval of the interviews extended from seven to 45 min. This also depended comprehensively on the type of respondents. Few replied well outside what was requested, and others responded concisely. The employees of the NWS were able to get a diversity of appreciated information in the interviews gained concluded their work. More diminutive interviews were also directed at diverse places, such as talk to at a bus stop, the railway clearing and the green fields. This verified stimulating as most people entered the declined discussion. Few interviews ended with a span of three and 6 min and provided insight into their valuations of the prevailing green spaces but were not encompassed in the appraisal.

The minimum size for a usable UGS is 300–400 m. Many green and forested areas are already on the outskirts of the green belt. The districts with predominantly Grün-der Zeit-style buildings have a high proportion of areas with high building density. However, green spaces in these areas are usually private or not accessible because they lie within courtyards. Therefore, they are climate-effective but only offer one recovery factor for a few people. The proportions are lower in Gries, Lend, and Jakomini, among other areas, where common inner courtyards are sealed. UGS safeguards have been implemented to protect areas from development, with several possible ways to create green space in Graz. The city can green or purchase open spaces from private individuals. The SC in the district of Lend, which is the focus of this work, is an example of a high-density area with considerable green space. Green spaces could be located in central locations connected to public transport, often in former industrial areas. Regarding city design, short distances between amenities and mixed-use neighbourhoods with living, working, shopping and recreation facilities are aspects to be emphasized.

3.1 Participation of citizens

Citizens often have little insight into the design and implementation of projects devised by urban planning officials in their city or district and are largely excluded from political decision-making processes. Can citizens, companies and interest groups help to directly shape their living environment and achieve more social sustainability through citizen participation? Citizen participation is often seen as a chore by administrators, economists and politicians, and it is often not fulfilled. The inclusion of city inhabitants can contribute considerably to current projects, as they are the ones who ultimately have to bear the consequences. The field of urban development can benefit from the knowledge and resources of as many different actors and disciplines as possible.

When designing green spaces or public spaces, citizens can offer decisive contributions to the further development of vacant areas, mobility issues and many other topics. All residents must be afforded freedom of expression, and their knowledge and ideas and solutions should be incorporated into public projects. The same applies to local companies. External impulses can change perspectives and are necessary to achieve social change, highlighting the importance of meaningful participatory processes.

3.2 Green laboratory—Test laboratory for urban greenery

The green laboratory (GL) was built to study the management of neighbourhood vicissitudes. The construction vessel was swapped by a new building, an “Urban Box.” NUSSMÜLLER architects planned this advanced, segmental, moveable wooden building. Project management has taken over the GBG building and the construction management of Graz GmbH. The project started in the spring of 2020 and will run for 3 years.

The crucial aim of the GL is the first-class provisional or succeeding use of the fallow property in the SC district formerly additional development. The five subgoals for the implementation of the GL are as follows;

- i. An innovative demo building: The urban box will be greened on the roof and equipped with a façade, with the goals of a district garden, rainwater management, biodiversity, efficient energy supply and the use of renewable energy sources;
- ii. The GL should be an open and easily accessible space where work, learning and exhibitions can take place, with a focus on the subject of urban greenery;
- iii. The GL can serve as an initiator the development of other fallow lands. The urban box is one locally flexible possibility, with green infrastructure as a central climate change adaptation measure in cities to be learned, experienced and self-implemented;
- iv. After the end of the project, the urban box can continue to be used at another location, i.e., transferred to another urban development area;
- v. Further usage scenarios and use cases for the urban box are to be established.

The building comprises of a multifunctional room with a kitchen (36 m²), an ante-room and a lavatory (around 10 m²), comparable to

the on-site ampule used by NWS. Given the unique use of this area, the terrain is comparatively gritty, consisting of Earth, numerous pieces of grit and some debris, so the soil is not suitable for implanting. A creative reactivation of the fallow area was achieved through district management and the resulting GL. Many different plant and vegetable types grow in the area, mainly from the NWS.

Together with the StadtLABOR team, options for the use of the GL include lectures, readings and film screenings on green topics; active use of the terrace with additional play equipment and seating options such as deckchairs to linger without being forced to consume; active involvement of citizens in the maintenance of green spaces and garden beds; international food festivals to integrate all nationalities residing in the district; sports camps; workshops; exchange markets; and much more. At the end of the interim period, the GL is scheduled to be transferred to another urban development area.

3.3 Urban greenery and neighborhood

The GL offers a place that is not a green space in the sense of a conventional park area, but has become a versatile area that is constantly developing through the collaboration of many different people and companies. Above all, when the weather is nice, many people enjoy the shared space. StadtLABOR runs for at least 2 days, represented by one or two employees each week, and five to seven people usually represent NWS. Interested people visit to find out more. Employees of the Science Tower often spend their lunch break at the GL or use the space to meet colleagues from the project consortium.

Most surveyed citizens knew of the GL because they lived in or worked in the district. Many neighbourhood residents who spend hours at the GL deserve special mention. These residents have planted and maintained many garden beds with various vegetables. The management and the district's employees provided the gardens with fertile soil and planted them. The vegetables are harvested for personal use and given away. People who use the space for their lunch break enjoy the many types of plants away from everyday office life, highlighting the benefits of urban greenery, a creative space and living together amid construction sites.

However, other respondents felt that the space was uninviting due to the construction site atmosphere. There is still a lack of trees, green meadows and seating, and the GL mainly attracts people who want to work on the beds or search for information on greening. A construction site fence bounded the space and the street until August 2022, separating the containers of other construction sites in the rear area. These elements only allowed the GL to offer limited access for non-residents, despite appearing publicly accessible. However, these barriers were removed in August, and the sidewalk has since led directly through the garden of the GL, opening up the private atmosphere (Figure 6).

The GL serves as a location for many events and campaigns. These events are very easy to access, after which the organizers or speakers are always available to answer questions from the public. Celebrations, joint lunches and neighbourhood walks have been offered, and crafted seed balls and natural cleaning products have been produced. Through the previously mentioned cooperation with the GiP Kindergarten in the Cool City, children's reading events and seminars on various green or city-related topics have been hosted. Before the conversion, through cooperation with the EggenLend youth center, events were sometimes organized with the young people. These tested technical and social



FIGURE 6
The new walkway through the GL.



FIGURE 7
Sensing beds in the Green Lab.

measures are regarded as models for similar positive projects in other districts or cities.

The efforts in the garden should be emphasized, such as insect hotels, smelling stations and small wooden sensory boxes (touch and smell). Furthermore, floor-feeling beds (Figure 7) are created and filled with various materials such as sawdust, pine-cones, stones, etc., which visitors can feel with bare feet. The various green walls and façades, both indoors and outdoors, require a considerable amount of care. Still, they improve the overall appearance of the space and have a climate-regulating effect.

4 Results and discussion

4.1 Challenges and need for action

Awareness and the number of visitors to the GL are constantly increasing, but there is a need for action. Only a few people visit the space daily (apart from those working there). Events and social networks are already reaching many people; however, many in the neighborhood are still unaware of the GL, and few non-residents use the community garden.

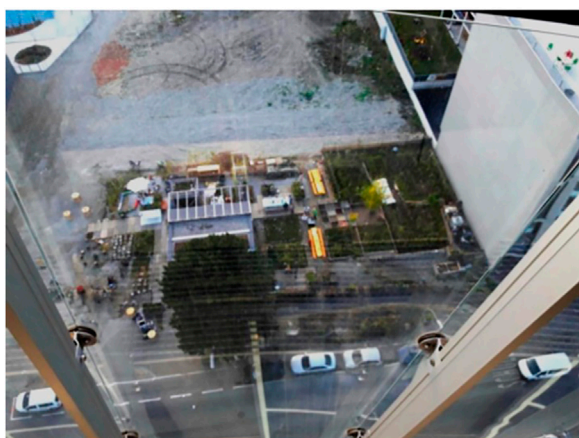


FIGURE 8
GL top view.

As revealed in the interviews, a construction site fence acted as a large barrier, separating the GL from Waagner-Biro Strasse. This made the area appear private. StadtLABOR made a long effort to have this fence dismantled; however, this process was delayed for a long time due to various conditions and obstacles for everyone involved. This small example shows how various authorities and the projects they are interested in can be delayed. At the back of the property, a container from the construction site of the elementary school was found. This was removed, resulting in a large open area in the rear, as shown in Figure 8. In the future, this area will be covered with sports fields built for the elementary school and the new middle school. Until then, multiple parties have an interest in the area. Parking areas interest some stakeholders, whereas others are interested in using the space as a recreation area for the community.

Various activities or events could be launched to attract people other than only environmentally conscious people, even if urban and climate-related issues should remain the focus of the GL. Due to the nearby construction site, the GL is not yet an optimal play location for children. StadtLABOR sees itself as an initiator and driving force in the GL, with the goal of users organizing themselves and planning activities. The GL could also function as a workspace or a coworking space.

Another approach would be to provide people with more green space without too many specified uses. However, it must not be forgotten that this is an interim use of the space for a limited time, which should always be communicated to the local population, and media involvement should be avoided (personal interview, 4 October 2022).

4.2 Experiences from SC

A considerable amount of information on SCs was available at the time of writing this paper. Interviewees who live or work in the study area were briefly asked about the construction sites and the SC project. Some of the experiences and statements of the

interviewees are summarized here. Smart cities such as the Science Tower in Graz usually have local peculiarities. However, the structure and application of smart cities are often similar throughout Europe. High quality of life is usually advertised in association with SCs, i.e., a car-free, resource-saving, energy-saving and architecturally appealing environment. SCs should feature short distances between amenities to achieve basic existential functions within one area, such as living, working, relaxing, re-source supply, waste disposal, education, living in a community and participating in traffic. Green spaces and public squares play an important role as consumption-free places.

Citizens are often excluded from planning and construction processes. Participatory processes often seem to lack motivation or resources. In the case of the Graz SC, a major potential problem is that the neighbourhood has a comparatively high percentage of people with a migration background or social or financial problems. Are their needs considered? These people are not sufficiently addressed in SC projects, even if subsidized housing is part of the project. It is uncertain whether they will participate in the smart forms of living and working or if there may even be a rift between them and new residents.

Interviewees suggest that non-profit and municipal projects should be prioritized in the SC. The Graz SC was not created as an exemplary international district, as evidenced by the assignment of street names. As few streets as possible within the new SC are re-named, and existing ones have been lengthened in order to promote integration with the surrounding area. Everything down to the garbage bins will be new in the SC, but integration will be a long-term goal.

It will be interesting to see whether sufficient space will be provided for green spaces, and such elements will be welcomed if time and financial constraints permit. The question also arises as to whether the SC area will quickly become more popular than a place of residence or a second center of Graz. The area still has a low density of public transport, gastronomy, local suppliers and leisure activities. Contrary to expectations, the residents of Waagner-Biro Strasse have become used to the noise of construction sites and vehicles being disturbed. Many interviewees expressed neutral to positive views towards the construction sites; otherwise, it was suggested nothing could happen (interviews 16, 19 July 2022). Most of the district's surveyed residents reported that they like to live there. Other neighbourhood residents spoke of imminent parking problems and fear of less privacy when the park is created or the continuation of existing issues. Since the dog park on the southern construction site was closed, many dog owners have moved to other places. Since then, some have taken their pets on more private paths and housing estates or let their dogs run free (interviews 14, 18 July 2022).

Including a dog park within the SC could prevent conflicts. Other conflicts have arisen with the dormitory residents, who often socialize on the rooftop terrace late at night (interviews 14, 18 July 2022). Many youth center interviewees said they often receive information about events late. The youth center will soon have to move from its current location. However, during the interviews in July 2022, it was unclear where the center would be relocated. Some interviewees reported feeling at the bottom of the priority list regarding information (interviews 13, 18 July

2022). Even if a youth center is only a small proportion of the population in the district, it is nevertheless an important institution and a stakeholder as other residents. Involving small and large stakeholders alike is important even if, in many cases, it does not correspond to direct participation but rather to information.

4.3 Qualitative and quantitative analysis

In an interview, the nature conservation officer of the city of Graz stressed the influence of green space on the welfare of residents. About 10 ha of green space influences the microclimate; it emits enough oxygen to affect the neighboring residential areas positively. In particular, small-scale green spaces have ecological and psychological effects insofar as residents experience the seasons and feel secure. An identity with one's living environment is promoted (personal interview, 27 September 2022).

Four respondents emphasized that having green space nearby was an important factor in their most recent apartment searches. Living near a green area is popular, which could explain the higher rents in areas with green spaces. Experts were asked whether creating new green space could increase surrounding apartments' rent. However, in recent years, no prominent green space creation has significantly changed the residential area (personal correspondence, 26 September 2022). Rents inevitably increase when green space is created or improved, affecting investments in public spaces. However, rents do not increase immediately but increase when the tenants change. This phenomenon must be accepted, and the only alternative would be not to invest in green spaces, which is also impossible (personal interview, 4 October 2022). New buildings have a high proportion of green space. If they are on or near a nature reserve, this feature is emphasized in rental advertising material, which can result in increased rents. Thus, more affluent people can afford to rent such apartments. In contrast, economically disadvantaged people often have to live in areas where the proportion of green space is lower (personal interview, 27 September 2022).

In interviews with residents, respondents described differences in recreation activities in public green areas from those in private gardens. The relaxation factor associated with gardens is high, although they are associated with maintenance work. However, interviewees described a positive feeling associated with harvesting what they planted. Therefore, for social activities, most people visit parks. A combination of both can result in a high level of recovery. Time in the countryside should allow city dwellers to switch off from everyday stress and offer an opportunity for relaxation. Are the green spaces in Graz large enough and sufficiently equipped to accommodate users and offer them relaxation and an escape from the stress of the city?

Many survey respondents reported that the green spaces in the districts of Graz are too small to enable them to switch off. Larger roads are usually within earshot. Many respondents reported that there is always something to look at and observe, although there are only a few footpaths. Less-designed ecosystems with minimal human intervention, such as forest or meadow areas, although they can better their stability secure, offer fewer opportunities for activities, which could cause people to no longer use such spaces,

making them counterproductive. A combination of green space with predetermined use and natural ecosystems seems to be an effective solution.

While the survey only provided a subjective assessment of health improvement from being outdoors, the intimation is that the green spaces alleviated respondents' health issues arising from sleeping problems and difficulties concentrating in association with high temperatures when few natural cooling solutions were available. Interestingly, none of the respondents complained about poorly designed green spaces. However, they mentioned a lack of shade and seating options, indicating that some green spaces and elements still receive insufficient attention. Furthermore, compared with other districts, Lend received a poorer evaluation for several indicators, e.g., housing satisfaction. The Lend district shows the second lowest housing satisfaction level afterwards Gries (Figure 9). A proportion of 41% of residents of von Lend reported that the quality of living has worsened in the last 5 years, whereas 39% reported no change.

The environmental quality pointer was classified according to various parameters, e.g., air quality, noise, convenience, paraphernalia and sanitation of public areas. Regarding environmental quality, it was shown that there is crucial requirement to take action or more categories (Figure 10). Action is urgently needed in Lend to address air quality; noise; apparatus in public and green places; and the hygiene of the public streets, squares, gardens and green fields.

The frivolous and relaxation value indicator concerns the offer, superiority and convenience of leisure and recreational places, play area and dog parks, and sports amenities, as well as the overall quality and accessibility of these elements (see Figure 11). The survey responses for this item varied widely. However, residents' satisfaction with this indicator in Lend was mid-range, indicating a greater need for action on the district's outskirts. In Lend, it is observed to play a crucial role concerning the tools in public parks (e.g., illumination, seats and drinking fountains) and pedestrian access to recreational places. The choice of bludgeons and their actions are viewed absolutely.

4.4 Recommendations for the construction of high-quality green spaces

After analyzing and discussing the literature and the interviews, the following recommendations are suggested for implementing changes in green spaces. The respondents generally favoured one high-quality green space that people could use.

- i. It makes sense to have many small green spaces in a city instead of a few large ones to strive for. With playgrounds, seating and enough shade, they are chosen especially for use for a short duration. Where possible, these should be connected by green corridors.
- ii. In addition to size, usability is an essential factor in green space planning, which can increase a park's sustainability. Many people should feel attracted to and use the park; thus, there should be room for games, sports, and quiet places to talk and observe. There should be separate dog areas and places to

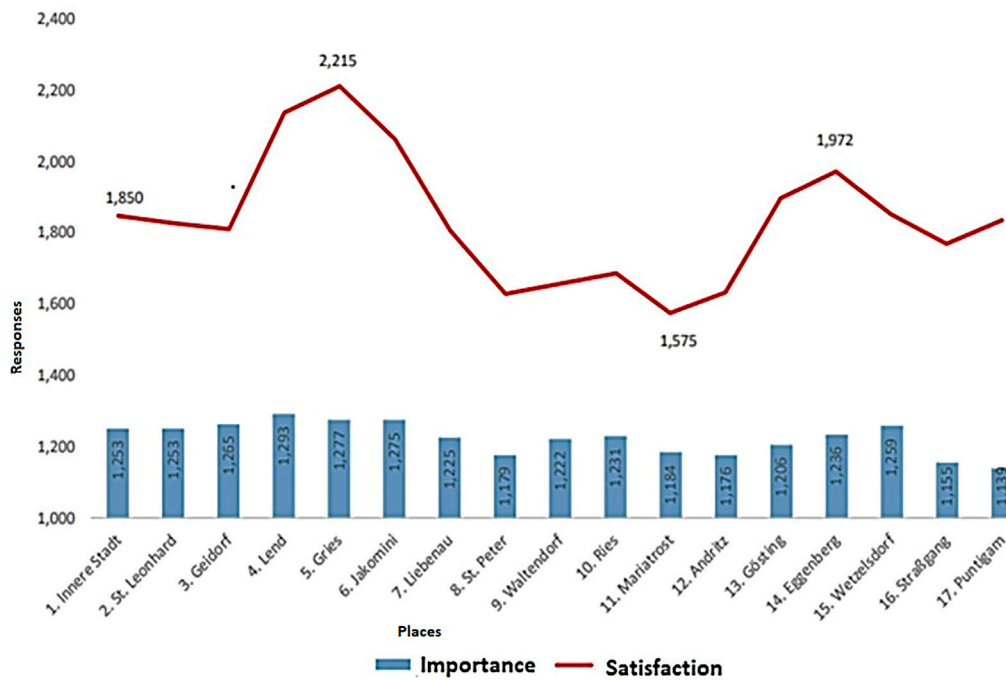


FIGURE 9 The satisfaction with and importance of the housing situation by district; the higher the value, the worse the satisfaction or the lesser the importance.

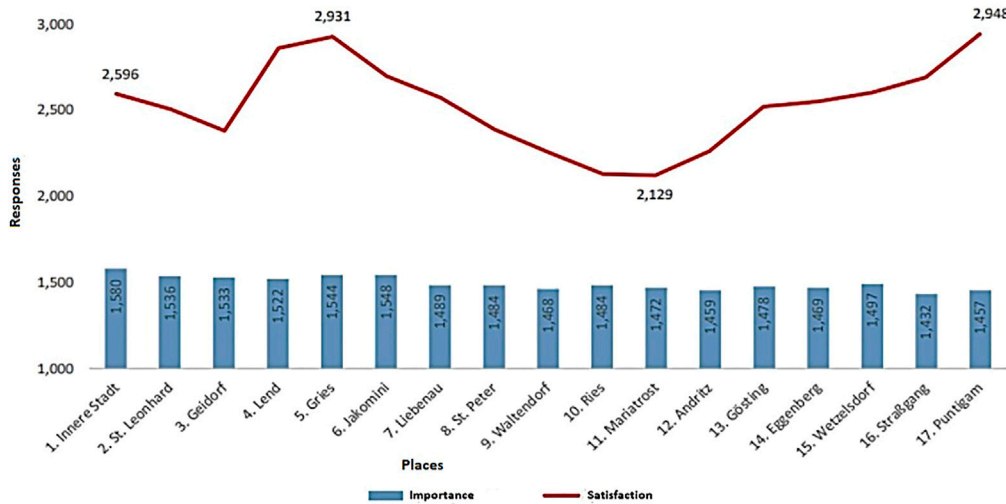


FIGURE 10 The satisfaction with and importance of environmental quality by district; the higher the value, the worse the satisfaction or the lesser the importance.

consume something (e.g., café). Furthermore, climate planning is relevant because of rising temperatures.

iii. The areas should be planned attractively. Regarding aesthetics, many design elements can flow into high-quality green spaces, e.g., water areas, crossing paths, places with a view, various plants and flowers, and architecturally appealing features such as benches.

iv. Regarding the formative component of green spaces, information boards could be placed in parks, and maps, diagrams, or sensory courses could be established. Children could impart knowledge to adults in a playful way by providing information about different plant species, the history of the park, or tips for things to do in the area.

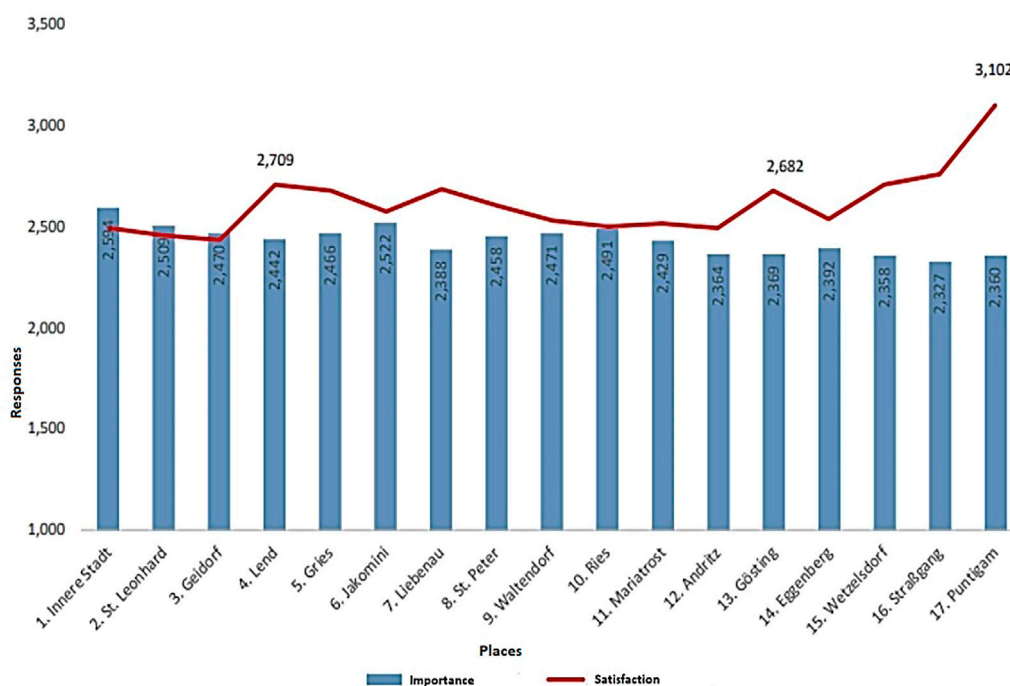


FIGURE 11

The satisfaction with and importance of recreation and leisure by district; the higher the value, the worse the satisfaction or the lesser the importance.

- v. Green spaces must be within walking distance. This leads to an increased use of the same and can result in more time playing outdoors. Every town should have a small, available recreational space with-in 300–400 m.
- vi. Exercise should be able to be integrated into everyday life, e.g., through attractive bike lanes. These and other similar actions should be pursued and continued, as they encourage people to be active. This action is considered very socially sustainable because of the varied and free access offered to everyone.
- vii. Combining a usable green area at home and public parks can lead to a high recreation level. The greening can be directed at the place of residence to improve the microclimate and have a beautifying effect. Public parks are a priority from a social point of view.
- viii. It is desirable that as many city dwellers as possible have a green space at home.
- ix. Consequently, urban funding for private initiatives would expand, and these subsidies should also be better marketed and communicated.
- x. When planning green spaces, people from the neighbourhood should be involved. Children are also important here. Not every neighbourhood is the same; therefore, different neighbourhoods require different equipment in the green space. The neighbourhood structure, above all, including the age structure, seems sensible here.

Finally, one can try out and implement more alternative ideas. The findings show that green spaces can bring people closer together and make public life more attractive.

5 Conclusion and future work

This objective of the research work is to evaluate which factors impact the use of UGS in the city regarding importance and satisfaction, as well as the health of city dwellers. This question was answered using the GL, as a case study. The literature research served primarily to answer the first two research questions related to the impact of urban greenery on humans and the environment. The following three research questions were predominantly addressed through qualitative interviews with residents and experts from Graz. The research questions posed at the beginning of this paper are now combined with knowledge from theory and empiricism to provide answers.

1. How do residents exploit and evaluate the urban green spaces (UGS) in Graz and in the city oasis of the green laboratory (GL)?

In Graz, small green spaces located near residential complexes are of central importance in addition to large recreation areas and parks. These spaces are easily accessible and equipped with the most necessary elements, such as play equipment and seating. For longer relaxation sessions, especially at weekends, residents often frequent green spaces on the outskirts or outside of the city to escape the hustle and bustle of city life. However, such visits require more time and, often, a vehicle. Strikingly, interviewed citizens identified a lack of creativity regarding different types of green spaces. This was reflected in their responses to which additional equipment and features they desired. This speaks to a rather monotonous green space design in Austria. A lack of pertinent examples indicates a

need for action regarding the creative use of free space. Survey respondents did not identify noise as a central disruptive factor regarding their use of green space.

The construction site noise around the GL is not a major problem for residents. Many park users feel threatened by other people using illicit substances such as alcohol or drugs. This seems to be a central theme in Graz, leading to large green spaces being avoided. This problem should be solved with targeted social support measures on the part of the city. Dog ownership is the subject of numerous discussions. Setting up dog parks in green spaces seems to be the most affordable solution to this problem.

The test laboratory for roof and facade greening, as well as the district garden and the lounge areas on the site, are currently establishing themselves as a meeting place for the district. Awareness in the district still has to be greatly expanded, and various events are regularly hosted. The comfort of the users of a green area and their level of benefit in terms of health were difficult to measure. This may be achieved by recording the number of visitors compared to another period. In addition, a map could be generated to show where most users congregate. Subjective reports can also be used to measure users' comfort and their contacts with other users.

2. What is the significant role of the GL in analyzing the UGS and how important the UGS in enhancing the living style (i.e., improving the quality of life) in the development of smart city (SC)?

The GL is a successful example of evaluating fallow land's social and ecological aspects, as an appropriable space was created in which methods for improving the urban environment can be tested. The quality of stay and the environment were at least improved on a small scale. However, there is still a need for further adaptations to the space. The GL is socially sustainable, and the active use of the GL, as a test laboratory for green infrastructure can bring physical and social health benefits. Every individual theoretically has access to the GL, but this has not yet happened in practice, and awareness needs to be raised so that more people can use the space. Employees of the non-profit employment project NWS account for much of the usage. Owing to their presence and activities, the GL is always busy. The NWS employees report, however, that other non-project persons are not currently using the GL as a workspace or meeting place. A step forward in the design and furnishing of the outside area can be observed by regular passersby. The employees' focused creativity could spark interest in other urban development areas, such as waste management, architecture or participation processes.

Visited by different people, the GL could increase community communication and reduce social conflicts. However, such developments need considerable time to establish a public profile. It would be desirable to achieve this within the runtime of the project. Forming a community that organizes and initiates events that will continue to exist even after the GL has been dismantled would also be highly desirable. The GL contributes positively to the interim use of the free spaces in the Waagner-Biro district, and its green surfaces positively influence the microclimate.

In the context of UPE, the GL can be seen as a link between natural, social and economic processes. As urban lots are condensed and increasingly built-up, work is being done to incorporate more nature into these new urban projects in the district and to stimulate new social processes, thereby strengthening the neighbourhood. According to UPE, nature is not independent of human action. Given the current knowledge of climate change, humans' passive role in urban spaces is no longer plausible. The GL is an important example of a holistic, integrated system in Graz.

Finally, the question arises as to how funding can be increased for public spaces and activities, given their effects on the health of city dwellers. This focuses attention on the role of the public in the important task of shaping areas under their control to correspond to the broadest possible spectrum of people. People should be encouraged to participate in active endeavours. Therefore, teaching them how to incorporate exercise into their everyday lives is important. This can be achieved by making walking and cycling more attractive, designing appealing green spaces and squares or providing support for creating private green spaces. In the case of new residential buildings and municipal instruments such as development plans, land use plans, etc., a sufficient allocation of green space must be ensured. Multifunctional centers should be created where residents can easily get around without motorized private transportation. Healthy eating should also be promoted, e.g., through farmers' markets. Socioeconomic inequalities should be balanced to the greatest extent possible, not least because they strongly impact health. Daily activities should be able to take place outdoors. This may require a partial redesign of green spaces. These offers should not be conceived of as forced happiness; they are practical and beneficial opportunities for city dwellers. Awareness can be created through various media. The greening and development of a city are not mutually exclusive and require compact structures interconnected by green space.

In the following paragraphs, we reflect on the methodological approach applied in the current research. Originally, the hope was to reach as many people as possible at the GL directly. However, fewer passersby visited the GL than expected, so interviewees had to be contacted at events.

Qualitative interviews are generally exploratory and identify the basic moods and opinions, which can later be critically examined. Owing to the mixed population structure in Lend, we aimed to include as many different people as possible in the survey population. However, this was not always possible. People from diverse demographic backgrounds and possibly holding different opinions and attitudes than those more environmentally conscious were more difficult to reach. To include such people, passersby in small green areas and bus stops in the district were spontaneously approached for a few days. Many were skeptical and unwilling to accept information about the interview process. Only about one-quarter of those approached publicly were willing to answer some questions. In several interviews, there were also language barriers on the part of the respondents. Most of these interviews were possible because they were not included in the evaluations. These interactions were nevertheless important to gather information about the basic mood of neighbourhood residents concerning the investigated indicators.

Almost all the interviews took place outdoors—many near Waagner-Biro Street. The audio recordings included street noise and the sounds of other people in the Green Lab, which made the transcription process difficult. However, as the interviews were transcribed immediately, the background noise did not result in any loss of information. In addition, it was necessary to perform the interviews on-site, as the location provided immediate impetus for discussion.

The numerous topics not explored in this work can be further investigated in future work. For example, it would be interesting to investigate further what might encourage city dwellers to use public and green spaces more. Furthermore, the topics investigated and assessed in this work will be re-examined after the completion of the SC area. Concerning the existing public green and open spaces, future work could examine how well they are used, whether they are multifunctional and promote activities and whether they improve neighbourhood relations. Furthermore, conflicts of use or unspoken access restrictions can be investigated. The methods applied in this work allowed for mainly subjective assessments. Therefore, it would be of particular interest to identify parameters with which the “success” of green spaces can be measured regarding objective improvements in health and quality of life. Urban green infrastructure is not the sole contributor to the happiness and health of city dwellers and the city’s environment, but it makes a significant contribution.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

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Author contributions

AA contributed to conception and design of the study. AA organized the database. AA performed the statistical analysis. AA wrote the manuscript. AA contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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