Smart urban management of green space

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Abstract

This paper aims to explore the concept and applications of smart urban green spaces within the context of sustainable cities. It emphasizes the importance of urban green spaces in providing ecological, social, and economic benefits, such as carbon sequestration, air and water purification, and improved well-being. The paper delves into integrating advanced technologies, including the Internet of Things (IoT), sensor networks, and data analytics, to create smart urban green spaces that optimize resource efficiency and enhance maintenance and operations. Sustainable practices, such as water conservation and biodiversity preservation, are examined for their role in ensuring the long-term viability and resilience of green spaces. The challenges and potential barriers to implementing smart urban green spaces, such as funding and governance issues, are discussed, as well as strategies for overcoming them. Additionally, the paper presents case studies and examples from around the world to showcase successful initiatives in creating smart urban green spaces. By exploring these concepts and applications, this paper contributes to the understanding and advancement of smart urban management of green spaces for sustainable cities.

Keywords: smart urban space, green spaces, Internet of Things (IoT), sensor networks, data analytics, sustainable cities.

1. Introduction

Smart urban green spaces and sustainable cities are two essential concepts that are gaining increasing attention in today's world. Cities worldwide face challenges that harm growth and the deterioration of green spaces, which harm the quality of life and the environment. Integrating green spaces into urban areas has become a prominent movement to create sustainable and livable cities (Rachmawati, 2019; Russo & Escobedo, 2022) . Smart urban management has emerged to address this goal effectively, leveraging technology and data-driven solutions to enhance the management and development of green spaces. Smart urban management seeks to improve the accessibility, sustainability, and overall societal benefits of green spaces through enhanced maintenance and administration (Roblek, 2019; Bedi, et al., 2020). This approach encompasses various elements, including technology and data utilization, mobility considerations, energy and resource management, community engagement, and effective governance and policies (Rachmawati, 2019). Smart urban green spaces play a crucial role in promoting sustainable cities and offer a range of benefits, including improved air quality, reduced urban heat island effect, biodiversity preservation, and enhanced well-being for residents (Rachmawati, 2019). However, effective management is essential to maximize these benefits and ensure the long-term sustainability of green spaces. Efficient management practices enable optimizing green space utilization, resource allocation, and maintenance activities. Technology and data-driven solutions provide real-time monitoring and analysis of environmental parameters, enabling proactive decision-making and responsive maintenance practices (Roblek, 2019). For instance, smart irrigation systems can adjust water usage based on weather conditions and plant needs, reducing water waste and promoting water conservation (Bedi, at all., 2020). Similarly, intelligent lighting systems can enhance energy efficiency by adapting to occupancy patterns and natural light availability. Community participation is another vital aspect of smart urban green space management. Engaging residents in the planning,

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design, and maintenance processes fosters a sense of ownership and promotes the community's well-being (Rachmawati, 2019). It allows for incorporating diverse perspectives and preferences, ensuring that green spaces meet the specific needs of the local population. Furthermore, effective governance and policies are critical in supporting smart urban management of green spaces. Clear guidelines and regulations facilitate technology integration, encourage sustainable practices, and promote stakeholder collaboration (Rachmawati, 2019). Public-private partnerships and participatory planning processes can also enhance the effectiveness of green space management efforts. Smart Urban Green Spaces use technology and innovative design to develop visually beautiful green places that are also environmentally favorable and socially inclusive (Liu, et al., 2021; Khan et al., 2022). By incorporating features such as smart irrigation systems, renewable energy sources, and green roofs, these spaces help to mitigate the consequences of climate change, reduce the effects of urban heat islands, and improve air quality (Shan et al., 2021).

On the other hand, sustainable cities are designed and developed to address current demands without jeopardizing future generations' ability to meet their needs (Chang & Das, 2020). This covers energy efficiency, waste minimization, and utilization of renewable resources. Sustainable cities strive to create a balance between economic growth, social well-being, and ecological health (Nitoslawski et al., 2019). Smart urban management of green spaces offers various benefits, including bettering the overall purity of the air and water, reducing the heat island effect, increasing biodiversity, and providing social and recreational benefits (Russo & Escobedo, 2022). Using technology and data, smart urban management improves the efficiency and effectiveness of urban governance, promotes social and environmental sustainability, and enables informed decision-making by city planners and managers to ensure efficient and effective resource utilization. Together, Smart Urban Green Spaces and Sustainable Cities indicate a movement in urban planning toward a more holistic approach, prioritizing the well-being of people and the planet (Bhattacharya et al., 2020). As continue to face the challenges of urbanization, these concepts play an increasingly important role in shaping future cities (Mortaheb & Jankowski, 2023). The absence of effective management in urban green spaces can lead to various risks and damages; without proper management, urban green spaces lack adequate drainage systems, leading to increased surface runoff during heavy rainfall, which results in flooding. Also, inadequate control of energy resources can result in excessive energy consumption, contributing to environmental degradation and higher carbon emissions (Khan et al., 2022). Climate change poses various risks to urban areas, including increased frequency and intensity of extreme weather events such as heatwaves, storms, and heavy rainfall. Without effective management, cities are ill-prepared to mitigate and adapt to these risks, which results in heat-related illnesses, property damage, disruption of infrastructure, and compromised public safety (Razmjoo et al., 2021). Urban green spaces play a crucial role in supporting biodiversity and ecological balance; without proper management, these spaces suffer from habitat destruction, invasive species proliferation, and pollution, leading to biodiversity loss and ecological degradation; this disrupts ecosystem services and negatively impacts the overall health of urban environments (Basnou et al., 2020). The absence of effective management leads to declining residents' overall quality of life and loss of opportunities for recreation, relaxation, and connection with nature. Additionally, inadequate management may result in poor air quality, noise pollution, and limited access to green spaces, which harm physical and mental well-being. The study aims to provide insights into the relationship between smart urban management and green spaces and offer practical recommendations for city planners and managers to enhance the quality of life and environmental sustainability in urban areas; the study holds significant importance in urban development and sustainability. This study addresses the pressing need for effective and sustainable management of urban green spaces. However, while considering this approach's potential benefits and limitations, the research problem lies in understanding the determinants and criteria of innovative urban management and its impact on the city's green spaces.

2. Literature review

Smart urban management, which integrates data-based technology and solutions to achieve city sustainability, has gained significant attention in recent years. Smart urban management substantially impacts urban green space management (Bedi, at all., 2020; Bhattacharya et al., 2020). Traditional approaches to managing urban green spaces were often manual and subjective, resulting in suboptimal outcomes (Masik et al., 2021).

Several case studies have demonstrated the benefits of smart urban management in transforming green spaces and enhancing sustainability. For example, the High Line Park in New York City showcases the successful conversion of an abandoned elevated railway into a vibrant urban park using smart technologies for irrigation, lighting, and visitor management (Chondrogianni & Stephanedes, 2022). The park's smart irrigation system adjusts watering schedules based on weather conditions and soil moisture levels, ensuring efficient water use. Similarly, the Singapore Gardens by the Bay project incorporates smart technologies to optimize energy consumption, climate control, and water management, resulting in a sustainable and visually stunning green space (Michelam et al., 2021). Literature and studies have explored the multitude of benefits associated with urban green spaces, including climate change mitigation, improved physical and mental health, increased biodiversity and environmental resilience, and economic advantages (Liu, et al., 2021; Khan et al., 2022; Masik et al., 2021). However, many studies highlight the challenges of promoting green spaces in cities, such as limited space, maintenance and management, equality and access, and technological integration (Russo & Escobedo, 2022; Bedi, at all., 2020). Strategies such as multifunctional design, community participation, innovative financing, and data-based planning have been suggested to overcome these challenges (Khan et al., 2022; Razmjoo et al., 2021). The implementation of smart urban management of green spaces faces its own set of challenges, including the high cost of technology and the need for skilled personnel to operate and maintain systems (Khan et al., 2022; Hasan & Al-Khafaji, 2021; Toan & Nhu, 2020). It is important to note that privacy concerns related to data collection and usage must be addressed to ensure stakeholders' confidence in the systems (Roblek, 2019; Razmjoo et al., 2021). However, by leveraging smart technologies, cities can optimize resource use, enhance maintenance practices, and improve the overall user experience of green spaces. These technologies enable real-time monitoring of environmental parameters, efficient resource allocation, and data-driven decision-making.

3. Green Spaces

Green spaces are essential components of smart urban management and are commonly called green open spaces, including parks, pastures, forests, grasslands, farmlands, and other natural spaces (Danilina & Majorzadehzahiri, 2020; Parasher et al., 2019). Green spaces refer to vegetation covered in parks, gardens, forests, and other natural areas. These spaces provide a range of benefits to both humans and the environment (Shan et al., 2021). Green spaces are essential for several reasons. Firstly, Green spaces provide various ecosystem services, such as regulating the climate, improving air and water quality, and supporting biodiversity by providing habitats for various plant and animal species.

Additionally, green spaces provide recreational opportunities for people, including physical activity, relaxation, and social interaction options. They also contribute to a community's aesthetic value, enhancing residents' overall quality of life (Danilina & Majorzadehzahiri, 2020; Basnou et al., 2020). In recent years, there has been growing recognition of the importance of green spaces for human health and well-being (Chondrogianni & Stephanedes, 2022). Spending time in green places has been shown in studies to have several significant effects on mental and physical health, including stress reduction and mood enhancement and promoting physical activity. As a result, many cities and communities invest in creating and maintaining green spaces, aiming to improve public health, environmental sustainability, and overall quality of life (Masik et al., 2021), (Chondrogianni & Stephanedes, 2022). A growing body of scientific research supports the

importance of green spaces for human health and well-being. Studies found that exposure to green spaces is consistently associated with favorable health outcomes, including reduced stress, improved mood and cognitive function, and lower Obesity, diabetes, and cardiovascular disease are all on the rise. One mechanism through which green spaces may promote health is by providing opportunities for physical activity (Russo & Escobedo, 2022; Rachmawati, 2019). Green spaces also promote mental health by providing stress reduction and relaxation opportunities. Studies found that spending time in nature reduces cortisol levels, a hormone linked to stress, and improves subjective feelings of well-being. Another study found that exposure to green spaces improves attention and cognitive function, potentially due to the restorative effects of nature on mental fatigue (Danilina & Majorzadehzahiri, 2020). Additionally, green spaces benefit human health by improving air and water quality. Trees and other vegetation help filter air pollutants, minimizing the likelihood of respiratory and cardiovascular disease (Al-Taee, 2021). Green spaces also help to reduce the risk of flooding and improve water quality by absorbing and filtering rainwater (Razmjoo et al., 2021; Mortaheb & Jankowski, 2023). Smart urban green spaces offer a range of benefits to residents and the environment. Using technology to improve sustainability and efficiency, smart green spaces reduce urbanization's environmental impact and decrease climate change's effects (Bedi, at all., 2020). Additionally, by providing residents with more accessible and user-friendly green spaces, smart urban green spaces improve mental and physical health outcomes and enhance the overall quality of life (Ramaiah & Avtar, 2019). As smart technologies develop and become more affordable, I expect to see more cities and communities incorporating smart features into their green spaces (Figure 1). By leveraging technology to create more sustainable and user-friendly urban environments, I create healthier, more livable cities for all (Greopanta, 2020).

3.1. Smart urban governance enhances the management and maintenance of green spaces using data-based technology and solutions as shown 2, such as:

1) Conserving water by utilizing sensors to monitor soil moisture levels and plant health, improving irrigation efficiency, and reducing water waste (Chondrogianni & Stephanedes, 2022; Liu et al., 2020).

2) Enhancing biodiversity and supporting wildlife (Chang & Das, 2020; Nitoslawski et al., 2019).

3) Data-driven decision-making, where data analytics aid in improving maintenance schedules, reducing costs, and enhancing quality (Khan et al., 2022; Bernardo, 2019).

4) Improving accessibility, such as providing safe corridors and entrances (Chang & Das, 2020; Danilina & Majorzadehzahiri, 2020).

5) Promoting economic development by attracting tourists, increasing the value of real estate, providing opportunities for local businesses, and creating jobs in areas such as technology, data analysis, and maintenance (Liu et al., 2020; Danilina & Majorzadehzahiri, 2020).

Figure 1 Green space design as part of the city's urban management

3.2. Smart Urban Management Standards

Smart Urban Management Standards are guidelines and criteria defined in ISO 37120 Standard to ensure the effective implementation of Smart Urban Management practices in cities worldwide (Michelam et al., 2021). The development of standardized approaches and frameworks to guide cities in leveraging technology and data to improve urban systems and services is becoming increasingly important as the concept of Smart Urban Management gains momentum. These standards aim to provide cities with guidelines and criteria to effectively implement smart technologies and data-driven approaches, leading to enhanced urban planning, efficient resource management, and improved quality of life for residents (Bernardo, 2019). The need for such standards arises from recognizing that cities worldwide face similar challenges and can benefit from sharing best practices and adopting common frameworks. These standardized approaches facilitate knowledge exchange, collaboration, and the development of scalable solutions that can be applied across different urban contexts (Liu et al., 2020). By embracing Smart Urban Management standards, cities can pave the way for more intelligent, sustainable, and resilient urban environments. (Mortaheb & Jankowski, 2023). Smart Urban provides a framework for cities to develop and implement Smart Urban Management strategies aligned with best practices and considering each urban context's unique characteristics and challenges (Greopanta, 2020).

The development of Smart Urban Management Standards is a collaborative effort involving multiple stakeholders, including governments, industry, academia, and civil society (Michelam et al., 2021). These standards are designed to be flexible and adaptable, enabling cities to customize their approach to Smart Urban Management based on their specific needs and priorities. By adopting Smart Urban Management Standards, cities help ensure their Smart City initiatives are effective, sustainable, and equitable (Basnou et al., 2020). They also benefit from improved interoperability and data sharing, which lead to more efficient and effective urban systems and services. Smart Urban Management Standards are essential to creating more livable, sustainable, and resilient cities for all (Danilina & Majorzadehzahiri, 2020). The presented table showcases the primary indicators associated with each criterion identified in the review as crucial factors for smart urban management of green spaces:

Table 1 The criterion identified in the literature review for smart urban management of green spaces.

criteria	Main indicators
Efficiency of Energy	• Utilization of renewable energy sources. • Maximize energy consumption. • Energy-efficient lighting and equipment.
Conservation of Water	• Smart Irrigation System. • Water Saving Fittings. • Harvesting rainwater.
Biodiversity	• Selection of native plant species. • Provision of wildlife citizens. • Environmental corridors for the movement of innate life.
Ease of accessibility	• Provide accessible, safe passages and entrances. • Includes persons with disabilities or limited mobility. • Accessible amenities include seats, bathrooms, water fountains, and drinking sources.
Data Traffic Networks	• Use of data analytics for maintenance and management. • Decision-making for Management. • Predictive Analysis for Maintenance and Management. • Real-time monitoring of green spaces.
Skilled Workers	• Skilled personnel and workers are eligible for data analysis and decision-making. • Trained cadres to operate and maintain technology and systems.
Privacy & Data	• Compliance with data protection regulations.
Data Security	• Transparent data collection and management. • Secure data storage and management. • Protection of personal information.

3.3. Smart Urban Management Controls and Determinants for Green Spaces

Smart urban management controls and determinants for green spaces refer to the technologies and strategies used to monitor, maintain, and improve urban green space quality. These controls and determinants use data analytics, sensors, and other tools to optimize the use and maintenance of green spaces, making them more sustainable and user-friendly (Liu et al., 2020).

A smart irrigation system is one example of smart urban management control for green spaces. Sensors are used in this system to monitor soil moisture and weather data to optimize watering, reducing water waste and ensuring that plants receive the right amount of water. By reducing water usage, Smart irrigation systems aid in conserving water resources and reducing the environmental effect of green spaces.

(Russo & Escobedo, 2022; Chang & Das, 2020). Another example of smart urban management control for green spaces is a smart waste management system. This system uses sensors to monitor waste levels and optimize waste collection, reducing waste in landfills and improving the cleanliness of green spaces. By improving waste management, smart systems help to reduce pollution and enhance the environmental sustainability of green spaces (Shaheen & Hasan, 2018).

Determinants for green spaces are significant factors in smart urban management. For example, the design and layout of green spaces affect their accessibility and usability. Smart green spaces should be meticulously designed with well-planned paths, comfortable seating arrangements, and appropriate lighting to ensure inclusivity and ease of navigation for individuals across all age groups and varying abilities (Toan & Nhu, 2020). In addition to accessibility, the location of green spaces is a crucial determinant for effective smart urban management. Green spaces should be strategically situated in areas that are easily accessible to residents, such as in proximity to public transportation hubs or residential neighborhoods. By strategically locating green spaces, cities can encourage greater general utilization, improve public health outcomes, and reduce environmental impact (Masik et al., 2021; Michelam et al., 2021). One approach to mitigating the adverse effects on concrete durability is carefully selecting sustainable construction materials. While green building practices often prioritize environmentally friendly materials, ensuring they possess the necessary durability characteristics for long-term performance is essential. This can involve considering alternative cementitious materials, such as supplementary cementitious materials (e.g., fly ash, slag) or pozzolanic materials, that can enhance the durability properties of concrete.

Furthermore, proper design and construction practices are crucial in mitigating durability concerns. Adequate attention should be given to appropriate mix design, proper curing techniques, and effective quality control measures during construction. This includes ensuring the concrete mixture is proportioned correctly, compacted, and cured to achieve the desired durability performance. In addition, using protective coatings and sealants can offer an extra layer of defense against environmental deterioration. These coatings can help enhance concrete structures' resistance to moisture ingress, chemical attack, and carbonation. Regular maintenance and inspection of green buildings are also essential for identifying and addressing potential durability issues. Implementing a proactive maintenance program that includes periodic inspections, repairs, and necessary rehabilitation measures can help ensure concrete structures' long-term performance and durability. Smart urban management controls and determinants for green spaces are essential for creating sustainable and user-friendly urban environments. By leveraging technology and design to optimize the use and maintenance of green spaces, cities create healthier, more livable communities for all. Green space management encompasses a range of measures and factors essential to ensuring these spaces' effective management and maintenance. These include the use of:

1. Technology, such as sensors, data analytics, and artificial intelligence, to enhance efficiency (Liu et al., 2020).

2. Effective organization: involves defining the roles and responsibilities of various stakeholders, ensuring communication and cooperation among them (Bernardo, 2019).

3. Resource management: involves allocating and using resources, such as funding, personnel, and equipment, to maintain and improve green spaces (Parasher et al., 2019).

4. Dialogue: involves engaging stakeholders to understand their needs and interests and apply them in decision-making to align initiatives with society's needs and priorities (Rachman et al., 2018).

5. Agencies responsible for managing green spaces must ensure equity and social justice, making them accessible to all members of society (Mortaheb & Jankowski, 2023).

6. The research design focuses on the management aspects of green spaces rather than their utilization. It emphasizes that creating green spaces should encompass multiple functions, such as serving as recreational areas, managing rainwater, and enhancing air quality, to maximize their benefits and efficiency. Additionally, the paper suggests the utilization of performance measurements to assess the effectiveness of these green spaces.

4. Theoretical Framework

Smart urban management of green space is essential to sustainable urban development (Bedi, at all., 2020). The theoretical framework for smart urban management of green space draws upon several key concepts from urban planning, sustainability, and technology. The framework emphasizes the need to harness technology and data to optimize urban green space management and operation to achieve sustainability, resilience, and quality of life for urban residents (Rachman et al., 2018). The critical concept of smart urban management of green space is the concept of "smart urban governance," which refers to using technology and data to improve urban systems and services. In green spaces, this means using sensors, surveillance systems, and other techniques to track environmental conditions, monitor plant growth, and manage water levels (Greopanta, 2020; Rachman et al., 2018). Another critical concept is environmental management, which involves using ecological principles and practices to manage resources and promote sustainability (Mortaheb & Jankowski, 2023). This includes techniques such as sustainable landscapes (Basnou et al., 2020), water conservation (Danilina & Majorzadehzahiri, 2020), and integrated pest management (Bedi, at all., 2020), which help reduce the environmental impact of urban green spaces. One key concept is the idea of smart cities, which refers to using technology and data to improve urban systems and services. Smart urban management of green space builds upon this concept by focusing specifically on the management and operation of urban green spaces, which are critical components of sustainable cities (Masik et al., 2021; Greopanta, 2020).

Another essential concept is the idea of green infrastructure, which refers to natural and semi-natural systems that provide a range of ecological, social, and economic benefits. Parks, gardens, and green roofs are examples of urban green areas that represent a form of green infrastructure that helps mitigate the effects of urbanization, such as air and water pollution while providing recreational and aesthetic benefits (Basnou et al., 2020; Ramaiah & Avtar, 2019). The framework also draws upon sustainability principles, emphasizing balancing economic, social, and ecological factors in urban planning and development. Smart urban management of green space seeks to achieve sustainability by optimizing the use of resources, reducing waste and pollution, and promoting social equity (Bhattacharya et al., 2020).

4.1. Smart Urban Management

Smart urban management is a relatively recent concept that has emerged in response to the challenges posed by rapid urbanization and technological advancement (Khan et al., 2022; Nitoslawski et al., 2019; Chondrogianni & Stephanedes, 2022). The idea traces its roots back to the early 2000s when the philosophy of smart cities and the importance of effective governance began to gain traction; effective governance was recognized as a critical factor in ensuring the successful implementation and management of smart urban initiatives. During that time, the focus was on utilizing various technologies such as the Internet of Things (IoT), Data Analytics, and Smart Grids and systems to enhance the quality of life for city dwellers, with a particular emphasis on

sustainability and efficiency (Liu, et al., 2021; Michelam et al., 2021). Over time, the concept of smart urban management has changed when new technologies have emerged, such as the Internet of Things (IoT) (Khan et al., 2022), data analytics (Khan et al., 2022; Liu et al., 2020), and artificial intelligence (Bernardo, 2019). These technologies have enabled urban managers to gather and evaluate enormous amounts of data to make better decisions and choices about urban space management (Chondrogianni & Stephanedes, 2022). Smart urban governance involves using technology and data to manage various aspects of urban life, such as transportation, energy, public services, and environmental sustainability (Danilina & Majorzadehzahiri, 2020). The primary goal is to improve resource utilization, minimize waste, increase efficiency, and improve the quality of life for the city's inhabitants (Parasher et al., 2019).
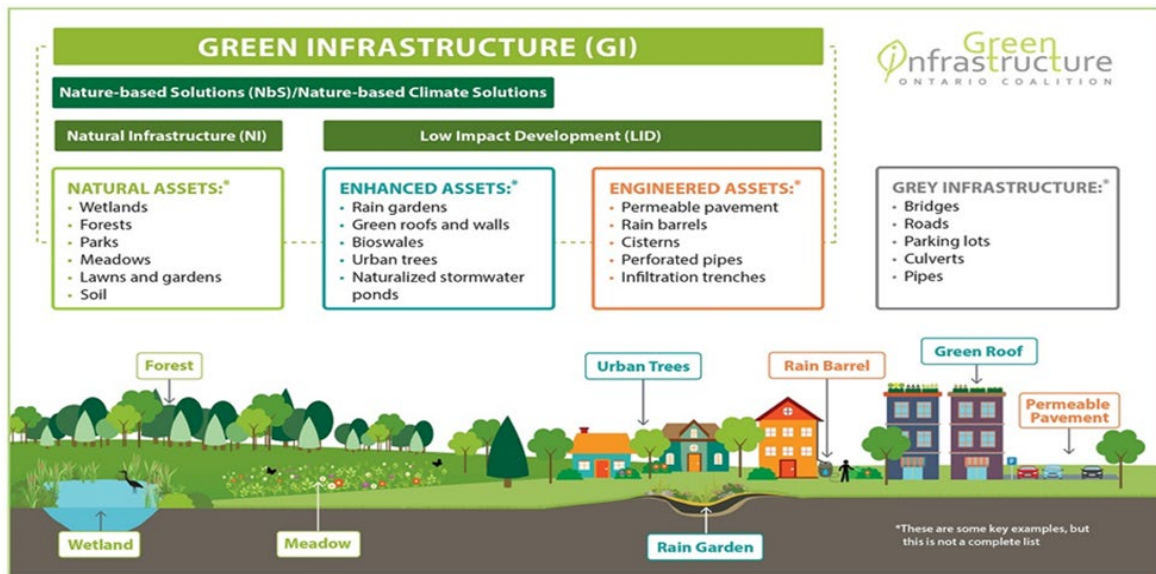
Figure 2 Types of green infrastructure in the City's urban management

Smart Urban Management aims to address these challenges by using data-driven approaches to optimize urban systems, improve governance and decision-making, and enhance the quality of life for urban residents (Russo & Escobedo, 2022; Roblek, 2019). Smart Urban Management is closely linked to the broader field of Smart Cities, which seeks to leverage technology and innovation to create more livable, sustainable, and resilient cities (Figure 2). Smart Urban Management is focused on managing and operating urban systems, including transportation, water and waste management, energy, and public services (Khan et al., 2022). Smart Urban Management uses modern technology such as data analytics, machine learning, and other advanced technologies to optimize these systems in real-time, reducing costs, improving efficiency, and enhancing urban residents' overall quality of life (Toan & Nhu, 2020; Danilina & Majorzadehzahiri, 2020). Smart Urban Management has the potential to revolutionize the way cities are managed and operated, enabling more efficient use of resources, reducing environmental impacts, and improving the overall sustainability of urban areas (Liu et al., 2020). However, there are also challenges associated with implementing Smart Urban Management, including data privacy, equity, and governance issues. As such, it is essential to approach Smart Urban Management with a holistic and inclusive perspective, considering the requirements and viewpoints of all stakeholders in the urban ecosystem (Nitoslawski et al., 2019).

Technology is a crucial enabler of smart urban management of green space, providing data collection, analysis, and communication tools. The framework emphasizes using digital technologies such as sensors, GIS mapping, and mobile applications to monitor and manage urban green spaces in real-time, enabling more efficient use of resources and improved decision-making (Khan et al., 2022; Ramaiah & Avtar, 2019). The Smart Urban Green Space Management Framework also emphasizes the importance of cooperation and community participation (Toan & Nhu, 2020).

This includes working with local stakeholders, such as residents, businesses, and community-based organizations, to identify their needs and priorities and involve them in green space planning and management (Chang & Das, 2020; Nitoslawski et al., 2019). This helps build support for green space initiatives and ensures that they respond to society's needs and preferences (Roblek, 2019; Nitoslawski et al., 2019).

5. Case studies, examples of best practices, and innovative solutions to enhance knowledge and awareness of smart urban management of green spaces in different cities.

These case studies provide practical examples of how smart urban management is applied to improve the availability and quality of green space in the city and to enhance knowledge and awareness of smart urban management of green space among policymakers, planners, and other stakeholders, and how it be effectively implemented in different cities. These include:

1. Singapore City (Singapore): The "City in a Garden" concept in Singapore is a holistic approach to urban greenery, and it involves the collective efforts of various designers, landscape architects, and urban planners. While there isn't a single project or specific designer associated with the entire concept, several notable projects and institutions have contributed to Singapore's green spaces. Gardens by the Bay project was designed by a team of landscape architects from Grant Associates, WilkinsonEyre, and Atelier One. Gardens by the Bay is a sprawling nature park featuring Supertrees, conservatories, and themed gardens. It showcases innovative horticultural and sustainable practices, including harvesting rainwater and solar energy. DP Architects and landscape architects from Atelier Dreiseitl designed the marina Barrage. Marina Barrage is a dam across the Marina Channel that creates a freshwater reservoir; it serves as a recreational space featuring lush green lawns, gardens, and a rooftop park with stunning city skyline views. Punggol Waterway Park project: This waterfront park was designed by landscape architects from Atelier Dreiseitl. It incorporates an artificial waterway, landscaped promenades, and themed zones, providing residents with a scenic and sustainable recreational area. Singapore Botanic Gardens was established in 1859. It is a UNESCO World Heritage Site and one of the oldest tropical gardens in the world. While the original design was influenced by various individuals, including Lawrence Niven and Henry Nicholas Ridley, subsequent additions and enhancements have been carried out by different architects and landscape architects (Toan & Nhu, 2020). This project exemplifies how smart urban management is used to promote sustainability.

Figure 3 Smart Urban Green Space Management in Singapore

2.Copenhagen, Denmark: Copenhagen, Denmark, manages and develops the city's green spaces using smart urban technologies. To improve the city's air and water quality and provide favorable environments for wildlife, these efforts include creating new parks and green areas and improving the design of existing green spaces (Chang & Das, 2020; Greopanta, 2020). Waste-to-Energy Plant Copenhagen is home to the famous Amager Bakke waste-to-energy plant, also known as Copenhill. While primarily serving as a waste management facility, it features a unique design incorporating a ski slope on its roof, allowing visitors to engage in recreational activities such as skiing and snowboarding. The Danish architecture firm Bjarke Ingels Group (BIG) designed the plant, and it has become an iconic symbol of sustainable urban development. Rooftop Gardens Copenhagen has

embraced the concept of urban rooftop gardens, utilizing underutilized spaces on top of industrial buildings to create green areas. While I have yet to get specific information about a rooftop garden covering industrial buildings with a ski slope, fertile hiking trail, and climbing wall, these projects may be conceptual ideas or proposals rather than realized projects. Port Transformation Copenhagen has undertaken various projects to transform industrial ports into vibrant urban spaces. One notable example is the transformation of the Nordhavn industrial port into a new urban district. The development includes public spaces, parks, promenades, and squares, providing residents with recreational areas and enhancing the city's green infrastructure. The specific designers involved in these port transformation projects may vary depending on the individual initiatives.
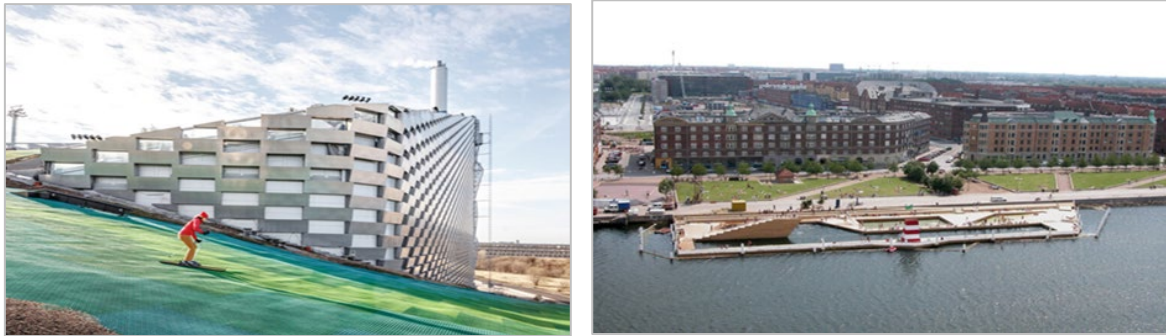
Figure 4 Sustainable urban planning for Barcelona

3.Barcelona City, Spain: Barcelona's "superblocks" concept is a city-wide initiative rather than a specific project with a single designer. The Barcelona City Council and the Institute for Urban Landscape and Quality of Life (IUQB) developed and implemented the concept in collaboration with various urban planning and transportation experts. (Shan et al., 2021; Basnou et al., 2020). The specific implementation of superblocks involves the reorganization of nine-block clusters, limiting vehicle traffic within these areas, and transforming the reclaimed space into pedestrian-friendly zones, green areas, playgrounds, and social gathering spaces. The goal is to prioritize pedestrians, promote sustainable modes of transportation, and improve the overall quality of urban life (Basnou et al., 2020). Garden irrigators also use sensors to track rainfall and humidity levels and adjust the amount of water used in each area.

Figure 5 Green Infrastructure Network of Barcelona (Basnou et al., 2020)

With special needs, Barcelona offers unique trails for the visually impaired, street seats, and metro tunnels, enabling them to walk around unimpeded. The city uses smart technology to

improve lighting poles and control lighting levels based on the number of pedestrians, contributing to energy conservation(Basnou et al., 2020). It encourages using environmentally friendly transportation methods such as electric bikes and clean buses. The city improves parking and parking systems using smart technologies (Razmjoo et al., 2021). Barcelona continues to enhance the quality of life of its residents and visitors and achieve sustainable development in the future.

4.Melbourne, Australia: The Melbourne Urban Forest Strategy is an overarching approach. It is a comprehensive strategy developed by the City of Melbourne, Australia, collaborating with various stakeholders, including urban planners, landscape architects, environmental experts, and community members. The strategy aims to increase tree canopy cover in the city, with a 40% tree canopy cover target by 2040. It encompasses a range of initiatives, including tree planting programs, community engagement activities, and the use of technology for monitoring and managing the urban forest (Mortaheb & Jankowski, 2023; Basnou et al., 2020; Alfriani et al., 2022) application of intelligent irrigation and design programs to improve water and soil quality in green spaces.

Figure 6 Roofs and green spaces in Melbourne

5.Dubai, UAE: Dubai is known for its modern infrastructure and innovative approach to urban development. The implementation of smart urban green space management is one such initiative that highlights the city's commitment to sustainable urbanization. By leveraging the latest technologies, Dubai has managed its green spaces efficiently, using smart solutions and involving residents in managing green spaces (Chang & Das, 2020). Smart irrigation systems in Dubai Parks and Resorts and Dubai Miracle Garden demonstrate the city's commitment to reducing water use and conserving its natural resources. These initiatives improve the city's sustainability and enhance the experience of residents and visitors by creating more livable and attractive urban environments.

6.Portland's Smart Park System: Implementing a smart park system in Portland, Oregon, involves integrating technology and data-driven management practices for the city's green spaces. It is a collective effort involving various stakeholders, including the City of Portland, urban planners, park management teams, and technology providers. The smart park system in Portland utilizes sensor networks to collect real-time data on soil moisture levels, weather conditions, and park usage. This data is then analyzed for informed irrigation, maintenance scheduling, and resource allocation decisions. The goal is to optimize the management of green spaces, ensuring their health and sustainability while maximizing their usability for residents and visitors.

5.1. Analysis of two study examples by specific criteria for smart urban management of green spaces

Smart urban management of green spaces is a critical component of sustainable urban development, and cities worldwide are exploring innovative approaches to optimize resource use and improve residents' quality of life. In this analysis, I examine two case studies of smart urban management of green spaces, Dubai City and Singapore City (Table 2), which are chosen as examples of smart urban management of green spaces based on their notable advancements in

implementing smart strategies and their commitment to sustainable urban development. Dubai City and Singapore City exemplify different approaches to smart urban management, making them exciting and valuable for comparison. By examining these case studies, we can identify key strategies, technologies, and policies contributing to successful smart urban management of green spaces. This analysis highlights the differences and similarities between the two cities, providing insights into effective practices that can be applied in other urban contexts. By focusing on specific criteria such as technology integration, stakeholder engagement, and data sharing, we can better understand the elements contributing to the success of smart urban management strategies for green spaces.

Table 2 Analysis of Two Study Situations According to Specific Criteria for Smart Urban Management of Green Spaces

criteria	First case study: Dubai City	Second case study: Singapore City
Energy Efficiency	Dubai **Green Building Regulations** and invested in renewable energy projects and smart grid technologies.	Singapore **Green Mark Scheme programs**, using energy-efficient appliances, and promoting sustainable transportation options.
Water Conservation	Use of **treated wastewater for irrigation** and promoting water-efficient technologies in buildings.	The city **collects and treats rainwater** and practices water reclamation.
Biodiversity	Many **Initiatives like** the Dubai Desert Conservation Reserve and Dubai Creek Rehabilitation Project.	The city has **designated nature** reserves, such as Bukit Timah Nature Reserve and Sungei Buloh Wetland Reserve, to protect native flora and fauna.
Easy Access	**Modern metro system**, well-connected road networks, and an expanding public transportation network.	The city-state has an extensive **public transportation network**, including a comprehensive subway system (MRT) and a well-connected bus network.
Secure data storage and management	They have invested in digital infrastructure data management systems and data security and have implemented measures to protect sensitive information.	**Robust cybersecurity** measures and data protection regulations: the city has a well-developed digital infrastructure and stringent protection laws.
Decision-making	Dubai employs **data-driven decision-making approaches**.	Singapore places a strong emphasis on **evidence-based decision-making**.
Skilled Personnel	Due to its numerous construction and development projects, **Dubai attracts skilled professionals from various fields**.	Singapore has a highly **skilled workforce with expertise in various sectors** and invests in education and training.
Privacy & Data	Dubai has **data protection regulations to safeguard privacy** and ensure responsible data management.	Singapore has **strict privacy laws and regulations governing** personal data collection, storage, and use.

Dubai City and Singapore City are chosen as case studies because they represent distinct geographical regions and have different approaches to urban development and green space management. Dubai City is known for its rapid urbanization and ambitious infrastructure projects. It has implemented innovative technologies and strategies to address the challenges of limited water resources and extreme climatic conditions. Singapore City, on the other hand, is a small island city-state in Southeast Asia known for its sustainable development practices and efficient urban planning. It has prioritized green spaces, biodiversity conservation, and community engagement in its urban management strategies. By comparing these two cities, we gain insights into different approaches to smart urban management of green spaces and identify best practices that can be adapted and implemented in other urban contexts. These case studies were selected to showcase diverse examples and comprehensively analyze smart urban management strategies. Furthermore, Dubai City and Singapore City are recognized globally for their efforts in sustainable urban development and have received accolades for their green initiatives. This makes them compelling case studies to examine to understand the factors contributing to their success and identify transferable lessons for other cities.

6. Discussion and conclusion

The results of the case study comparison between Dubai City and Singapore City provide compelling evidence for incorporating the "City in a Garden" concept and smart urban green space

management in urban planning and development. The case study comparison reveals that Singapore's holistic approach to urban greenery, embodied by the "City in a Garden" concept, has yielded significant benefits. The presence of well-designed and accessible green spaces has positively impacted Singapore's overall quality of life. The examples of Gardens by the Bay, Marina Barrage, Punggol Waterway Park, and the Singapore Botanic Gardens demonstrate how intentional design and sustainable practices have transformed Singapore into a livable and sustainable city. In contrast, while making strides in various aspects of urban development, Dubai City could benefit from a more comprehensive approach to urban green spaces. The comparison highlights the potential advantages of incorporating the "City in a Garden" concept and smart urban green space management practices in Dubai. By doing so, Dubai can enhance its sustainability efforts, improve residents' well-being, and create a more attractive environment for residents and visitors.

As a result of the analysis, Table 3 presented above offers a concise overview of the essential controls and determinants contributing to the intelligent management of urban green spaces. The rules encompass a range of critical aspects, including integrating technology, data-driven decision-making, stakeholder engagement, development of green infrastructure, efficient waste and water management, energy-efficient practices, and implementation of smart monitoring and surveillance systems. On the other hand, the determinants emphasize the significance of efficient resource utilization, biodiversity conservation, sustainable land use planning, climate change adaptation, community participation, accessible and inclusive design, maintenance and upkeep, and environmental education.

Table 3 Result of Smart Urban Management Controls and Determinants for Green Spaces

Smart Urban Management Controls	Determinants for Green Spaces
Technology integration	Efficient resource utilization
Data-driven decision-making	Biodiversity conservation
Stakeholder engagement	Sustainable land use planning
Green infrastructure development	Climate change adaptation
Efficient waste management	Community participation
Water resource management	Accessible and inclusive design
Energy-efficient practices	Maintenance and upkeep
Smart monitoring and surveillance	Environmental education

Together, these elements play a pivotal role in fostering effective and sustainable management of urban green spaces, ensuring their optimal functionality and long-term viability.

The study's findings emphasize that smart urban green space management contributes to sustainable urban development. It enables cities to optimize resource utilization, reduce environmental impact, and foster resilience in the face of climate change. By adopting sustainable landscape practices and responsible management of natural resources, cities can mitigate the adverse effects of urbanization and enhance their ecological footprint. One key finding is the role of smart urban management in promoting sustainable urban development. The study demonstrates that by adopting smart strategies and responsible natural resource management, cities can achieve sustainable landscape practices and reduce resource consumption and waste generation. This contributes to the population's overall well-being and helps create a more environmentally friendly and resilient city.

Moreover, the study emphasizes the economic benefits of smart urban green space management. Cities can stimulate economic growth and innovation by attracting companies specializing in green and smart technologies. This leads to job creation and the establishing of a sustainable business ecosystem that supports the transition to a greener and more efficient urban environment. Furthermore, comparing case studies underscores the economic benefits of smart urban green space management. Singapore's success in attracting companies specializing in green and smart technologies has stimulated economic growth and innovation. This has resulted in job creation and a sustainable business ecosystem. With its ambitious development projects and focus on attracting skilled professionals, Dubai City can leverage the potential economic opportunities of

investing in smart urban green spaces. The results also highlight the social benefits of well-planned urban green spaces. Accessible and well-maintained green areas promote physical and mental well-being, encourage community interaction, and enhance residents' overall quality of life. By prioritizing the availability and quality of green spaces, cities can create inclusive and equitable environments that cater to the diverse needs of their populations. Starting from the case study comparison results, we can draw a more convincing discussion that advocates integrating the "City in a Garden" concept and smart urban green space management in urban development. By adopting sustainable practices, optimizing resource utilization, and prioritizing the well-being of residents, cities can achieve a more sustainable, livable, and economically vibrant future. The experiences of Singapore and the potential benefits for Dubai highlight the importance of embracing these concepts in urban planning and development strategies.

7. Recommendations

Based on the benefits of smart urban management of green spaces, here are some recommendations for cities looking to implement these practices:

1. Technology and data adoption: Smart urban management should invest in sensors, surveillance systems, and data analysis tools to track environmental conditions, monitor plant growth, and manage resources like nutrient-rich water.

2. Using sustainable landscape practices: Smart urban management should use sustainable landscape practices such as native plant species, rain parks, and green roofs to promote biodiversity and reduce the environmental impact of green spaces.

3. Community engagement: Smart urban governance must engage with local stakeholders, including people, businesses, and community organizations, to understand their needs and priorities and involve them in green space planning and management.

4. Prioritize equality and accessibility: Smart urban governance must ensure that green spaces are available to all populations and prioritize investments in the neediest communities.

5. Monitoring and evaluating results: Smart urban management must use data and metrics to monitor the results of the smart urban management of green spaces, including improvements in air quality, water quality, and overall quality of people's lives.

6. Following these recommendations, cities successfully implement innovative urban green space management and create more livable, sustainable, and resilient urban environments.

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Resume

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