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A framework to understand the design guidelines of smart and sustainable urban open space Un marco para comprender las directrices de diseño en la planificación de espacios abiertos urbanos inteligentes y sostenibles

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MOHAMMAD SHARIF ZAMI
King Fahd University of Petroleum and Minerals, Saudi Arabia
mdszami@kfupm.edu.sa

SARA QWAIDER
King Fahd University of Petroleum and Minerals, Saudi Arabia
saraquwider@gmail.com

BAQER M. AL-RAMADAN
King Fahd University of Petroleum and Minerals, Saudi Arabia
bramadan@kfupm.edu.sa

MOHAMMAD A. HASSANAIN
King Fahd University of Petroleum and Minerals, Saudi Arabia
mohhas@kfupm.edu.sa

ABSTRACT Smart and Sustainable Urban Open Space (Smart-SUOS) are essential for improving the quality of life (QoL). They serve as hubs for leisure, social interaction, civic activities, and environmental benefits. This study provides a comprehensive overview of the types, design elements, and guidelines necessary to design Smart-SUOS. The study aims to formulate a framework to understand the design guidelines of Smart-SUOS. To achieve the aim, a critical review of the existing literature was carried out. The analysis of the secondary data gathered 13 essential landscape design elements (LDEs), 9 smart services and technology integration, and 10 design conditions (DCs) that were utilized to formulate a design framework of Smart-SUOS. The validated design framework included an additional LDE, 2 smart services and technology integration, and 2 DCs. The framework also includes a series of challenges and measures to overcome the challenges for the successful design of Smart-SUOS.

RESUMEN El espacio urbano abierto inteligente y sostenible (SUOS) es fundamental para mejorar la calidad de vida. Estos espacios funcionan como centros para el ocio, la interacción social, las actividades cívicas y los beneficios ambientales. Este estudio ofrece una visión integral de los tipos, elementos de diseño y directrices necesarias para diseñar SUOS. El objetivo del estudio es formular un marco conceptual para comprender las pautas de diseño de los SUOS. Para alcanzar este objetivo, se llevó a cabo una revisión crítica de la literatura existente. El análisis de los datos secundarios recopiló 13 elementos esenciales de diseño del paisaje (EDP), 9 servicios inteligentes e integraciones tecnológicas, y 10 condiciones de diseño (CD), los cuales fueron utilizados para formular un marco de diseño de SUOS. El marco de diseño validado incluyó un EDP adicional, 2 servicios inteligentes e integraciones tecnológicas adicionales, y 2 CD adicionales. El marco también incluye una serie de desafíos y medidas para superar dichos desafíos con el fin de lograr un diseño exitoso de SUOS.

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KEYWORDS quality of life, sustainable open space, landscape, design, guidelines

PALABRAS CLAVE calidad de vida, espacio abierto sostenible, paisaje, diseño, guías

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1. Introduction

According to United Nations (2021), cities are rapidly expanding where approximately 55% of the world's population is now residing. It is predicted that this population will be increased to 68% by 2050. The rapid urbanization strains on natural resources, QoL, raises worries and therefore, social sustainability is required in urban open spaces (UOS) (Razia and Abu Bakar, 2023). The quality of sustainable urban open space (SUOS) is a fundamental parameter in the developed habitat, influencing both physical and mental health (Das and Praharaj, 2022).

According to statistics across 1072 cities, the Sustainable Development Goal (SDG) report indicates that global accessibility to UOS is limited, especially among developing countries (UN Department for Economic and Social Affairs, 2023). Over 75% of 1072 cities have fewer than 20% of the total area dedicated to open spaces and roads. This percentage is substantially less than the UN's desire for 45-50% UOS and streets (Ahmimed, 2018).

UOS are essential for fostering social interactions, encouraging community involvement, and promoting a sense of unity and belonging (Azare et al., 2018). Urban multi-purpose open spaces provide economic, social and environmental advantages (Ibrahim et al., 2018). According to Savin (2020), SDGs of UN 2030 agenda worked on improving QoL for all and urged the provision of universal access to safe, inclusive, accessible to green public spaces, particularly for women, children, older and disabled persons by 2030.

Furthermore, the integration of technology and sustainable principles could create intelligent, environmentally friendly UOS that can enhance the QoL for residents and promote sustainable future (Savin, 2020). Recent studies have indicated that the use of smart technology and sustainable practices in UOS not only ensure a more efficient, friendly environment but enhances the overall public well-being and satisfaction (Itair et al., 2023).

This study aims to formulate a framework to understand the design guidelines of Smart-SUOS. The study provides an overview of the definitions, types, design criteria of SUOS. It explores the definitions of various types of UOS, along with the essential design elements and criteria required to design SUOS. In order to achieve the aim the study review the literature, formulate a design framework and validate it through questionnaire survey. The study outcomes inform, indicate future direction of urban, landscape development strategies, enhance the QoL and human well-being.

2. Methodology

This section details the research design, data collection methods and analysis procedures utilized in the study. Figure 1 illustrates the methodological framework. To achieve the aim, this study is divided into four distinct phases, each contributes to the development of the following phases.

The first phase involves the identification of the problem statement, formulation of research aim, and methodological framework. The second phase involves a desktop survey utilising and analysing secondary data to come up with an initial design framework. The review process utilised data extracted from 66 scientific research articles, 9 governmental reports and 3 books, majority of which was published during the last 10 years. This phase ensures a robust foundation drawn from credible and authoritative literature sources focused on key the topics such as defining UOS, smart

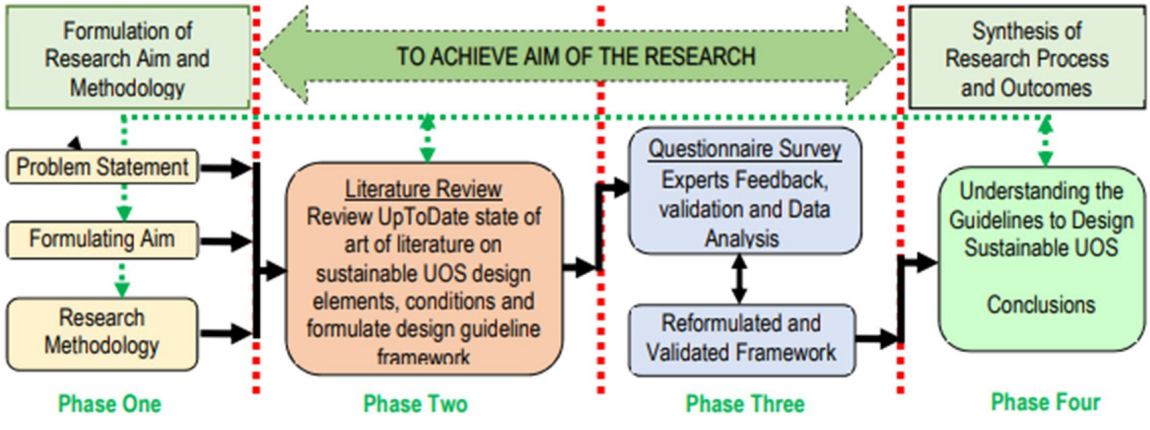

Figure 1: Methodological framework followed in this study. (2024)

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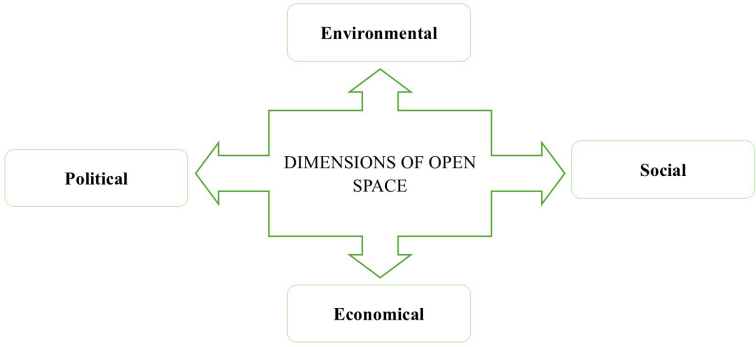

Figure 2: Dimensions of urban open spaces. Carmona et al., (2003)

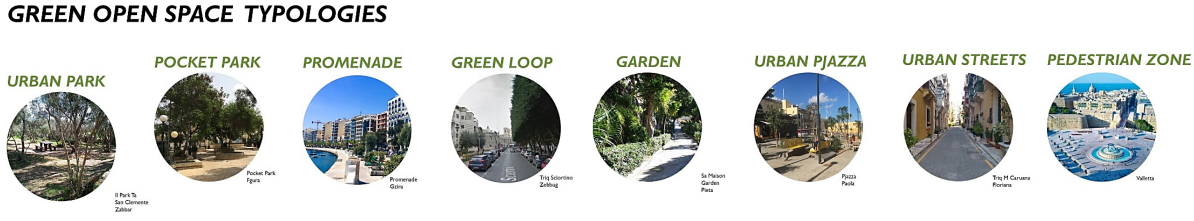

Figure 3: Forms of UOS. Scheiber, (2021)

technology integration, DCs of successful UOS, sustainable LDEs and guidelines. It establishes a firm understanding of the principles guiding the design of Smart-SUOS.

Third phase involved a questionnaire survey to validate the design framework. A google questionnaire survey was designed for the experts in the field. The selected expert team was comprised of 50 international architects, city planners, landscape and urban designers. Among the 50 experts, 36 were academicians and 14 were practitioners. The response rate was 60%. There were three sections in the questionnaire. First and second sections of the survey included LDEs, DCs, and smart elements respectively to be ranked according to their importance to design Smart-SUOS. Third Section included the framework in order to be validated by the experts. The data collected from survey reformulates and refines the design framework that helps to understand the guidelines of designing Smart-SUOS. Each section provided options to include experts' independent contributions whether there was missing LDEs, DCs, criteria, overlaps and interrelationships.

The collected data were analysed using Microsoft Excel. A five-point Likert scale was employed to assess the significance of each LDE, with response options ranging from 5 (Most Important) to 1 (Least Important). To quantify the relative significance of each element, the weighted mean and Relative Importance Index (RII) were calculated. Additionally, open-ended questions were utilized to capture experts' feedback on the design framework's implementation and to gather recommendations for its refinement. Lastly, the fourth phase comes up with design guidelines of Smart-SUOS, provides recommendations for future studies, and draws conclusions.

3. Literature review

3.1. Definitions, dimensions and typologies of UOS

UOS is defined as the sum of the areas of built-up regions of cities devoted to streets, wide streets, public parks, squares, recreational green areas, playgrounds, and open areas of civic buildings (Rakhshandehroo et al., 2017). According to Mehta (2014), open space is a place for interaction and cordial social interactions.

From a political perspective, open space can be understood as a concept that involves the tension between limitless spaces, allows for diverse uses, lacks coherence and bounded spaces that prioritize coherence at the expense of diversity (De la Llata, 2021). Its interconnectedness and diverse forms

are vital (Nikšič and Watson, 2018). Open space in architecture is a dynamic concept that prioritizes inclusivity, collaboration, technology to enhance user experiences and community engagement (Artopoulos et al., 2019). In landscape architecture, the concept of UOS reflects cultural values encompassing both aesthetic and functional needs (Yang et al., 2019). The usability of public spaces is essential for expanding human capabilities and supporting various activities, including autonomy, active mobility, and social interactions (Garau and Annunziata, 2022). The characteristics of physical components, like features, conditions, aesthetics, and safety influence the density and intensity of spatial use in public open spaces (Alwah et al., 2020). According to Carmona et al (2003), there are four dimensions of UOS as illustrated in Figure 2.

UOS can be classified into various categories based on their characteristics and purposes (Woolley, 2003). These classifications help us to understand the different functions and attributes that these spaces possess. Figure 3 depicts some common types of UOS (Sanei et al., 2017).

Open spaces can be culture and leisure oriented, providing venues for recreation and artistic expression while hosting events that promote community engagement (Zhang et al., 2022). Additionally, there are community-centred spaces that foster a sense of belonging and social interaction among residents. Table 1 summarizes the various forms of UOS.

3.2. Key principles, elements and conditions to design SUOS

Project for Public Spaces (2009) devised a model of attributes of public places (Figure 4). This model revolves around the concept of a place and identifies of four fundamental aspects: "Sociability', 'Uses and Activities', 'Access and Linkages', and 'Comfort and Images."

The attributes are encompassed by a circle of 'Intangibles', which, in turn, are embedded within the larger circle of 'key attributes'. It can stimulate discussions concerning the quality of public places. However, the origin and database used to develop

Typologies of uos	
Types	**Descriptions**
Community Parks	A community park is an open space in urban areas designed for recreation, social gathering, interaction, community engagement, relaxation and environmental purposes. (Adedayo et al., 2023).
Playgrounds	Playground spaces feature play structures, swings, and slides offering children opportunities for physical exercise and socialization. (Cohen et al., 2020).
Urban squares/plazas	These are centrally located open spaces that serve as gathering places for social activities and events (Yang et al., 2019).
Pedestrian streets	These are car-free streets designed for walking and socializing, often lined with shops and cafes (İnce Güney, 2014).
Green spaces	These include parks, gardens, and green corridors that provide natural elements, promote physical and mental well-being (Chen et al., 2016).
Civic spaces	These spaces serve as a platform for civic engagement, community events and considered as a formal space (Nared and Lamovšek, 2015).
Blue space	These are waterscapes in UOS that attract humans. They create blue image of the sea, sky and influence our physical and emotional experience (Hami and Abdi, 2021).
Large-scale public open spaces	The large-scale UOS facilitates all kinds of outdoor civic facilities with lush vegetation (Chen et al., 2016).
Waterfronts	Areas like riverbanks, lakeshores, coastal zones can be transformed into public open spaces with promenades, recreational facilities, water-related activities and views (Chen and Ma, 2023).

Table 1: Typologies of UOS. Compiled by authors from literature (2024)

Factors	**UOS**	**Smart UOS**
Accessibility/connected	Physically only	Physically and digitally
Visually attractive	Yes	Yes, and VR can add to it
Eco-friendly	According to city governance	Usually eco friendly
Sociable	Yes	Yes
Inclusive	Yes	Yes
Management	Governmental, rigid	Collaborative, adaptive
Event coordination	Regulated, time consuming	Spur of the moment
User experience feedback	Manual surveys, infrequent	Digital surveys, in the moment
Interaction with the space	Limited	Vast, evolving

Table 2: Comparison between UOSs and smart UOSs. Pancholi et al., (2015)

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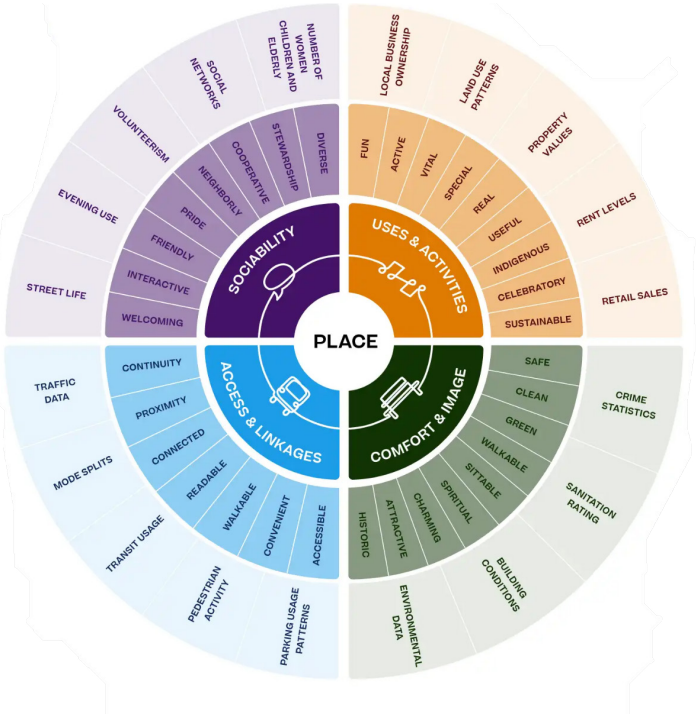

Figure 4: Attributes that makes a great place. Project for Public Spaces, (2009)

this model remain unclear as certain 'Intangibles', such as 'Sustainable' or 'Green', lack precise definitions. Moreover, the model fails to acknowledge that these intangibles can be interpreted differently, potentially leading to contrasting perspectives. For instance, the meaning of 'spiritual' may vary depending on an individual's spiritual beliefs. Consequently, it is not entirely evident that the essence of a remarkable public place depends on the unique experiences, values, ideas, senses, and perceptions of the individuals define it (Reich, 2020).

According to this model placemaking would enhance sociability and economic vitality by improving accessibility and walkability. It benefits mental, physical well-being by encouraging social interaction and attachment to the place. It helps reducing depression and stress while promoting cognitive functions. Active participation in recreation, especially in green spaces is linked to increased life expectancy and positive health outcomes (Reich, 2020).

Recently, sustainability has gained importance in urban planning and design with a focus on developing SUOS (Shebek et al., 2021). Nowadays, digitally networked UOSs are popular because of the dynamic data collection of urban residents' behaviour of pedestrian patterns, accessibility, mobility trends, and environmental information. Ongoing assessment informs the continuous improvement of smart public spaces to align with residents' preferences and enhance sustainability (Radwan et al., 2018). Pancholi et al. (2015) compared UOSs with Smart-UOSs.

According to Gracias et al. (2023) and Szczepańska et al. (2023), Smart-UOSs are driven by the idea of a smart city, which seeks to boost the QoL, engage residents in city governance, increase effectiveness of city infrastructure and functions. Figure 5 displays the Smart-UOS framework developed by Shahrour and Xie, (2021). This framework is made up of six layers, each is critical to ensure Smart-SUOS.

Smart-SUOS is vital for several reasons, namely human wellness, economic growth, transforming vacant spaces into productive areas, improving public utilities, suppressing crime rates, and minimising environmental impact (Radwan et al., 2018).

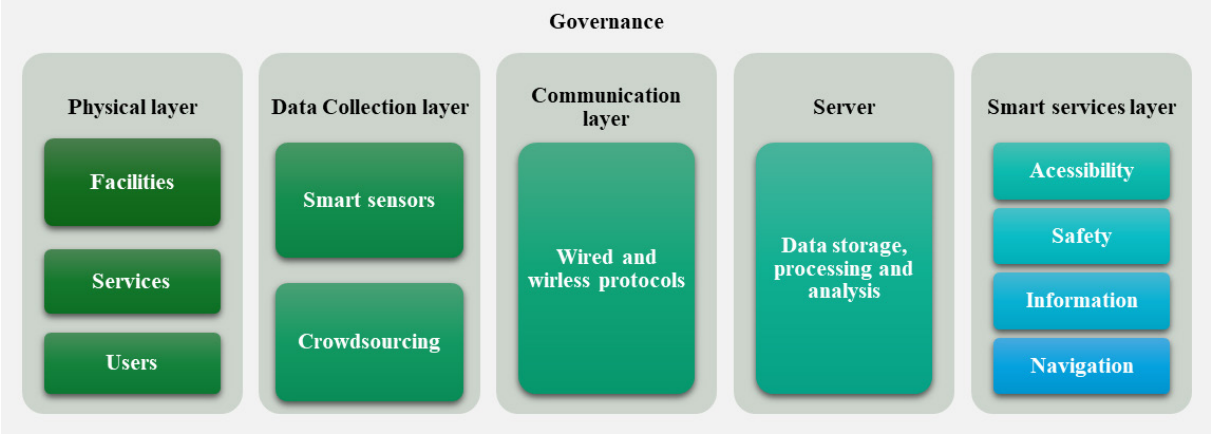

Figure 5: Framework layers of smart open space. Shahrour and Xie (2021)

Design principles to create suos		
Key Design Principles	**Auxiliary Design Principles**	**Descriptions**
Environmental Considerations	Microclimatic amelioration	Transforming contaminated post-industrial landscapes into sustainable public parks can mitigate urban heat, enhance human health and well-being (Dupper, 2021). A sustainable and resilient design approach addresses the effects of climate change (Mussinelli et al., 2020).
	Ecosystem services	SUOS should reflect the social and environmental complexity of a community by including regulations that ensure ecosystem services compensating any losses (Valente, 2020).
	Flexible open spaces	Providing appropriate flexible UOS is crucial, especially in light of the COVID-19 health emergency to ensure inclusivity in areas for communal interaction (Franchino and Frettoloso, 2020).
Socio-Cultural Considerations	Social success	Creating comfortable arenas where people of different backgrounds, genders, ethnicities can benefit from social interaction (Askari and Soltani, 2019).
	Inclusivity	SUOS should be designed for all age groups, activities, events, gatherings, and promoting social sustainability (Jagtap and Singh, 2019).
	Community involvement	Community engagement and collaboration among the public sector, private sector, and residents are essential for sustainably managed UOS (Sujatini, 2017).
Economic Considerations	Economic growth	SUOS can enhance the economic growth by improving the QoL, aesthetic quality, and walkability (Jayakody et al., 2018).
	Cost-effectiveness	Designing public urban parks with low initial and maintenance costs is important to ensure their long-term sustainability (Dupper, 2021).

Table 3: Design principles of SUOS. (2024)

In Smart-SUOS people should have access to data about the UOS layout (navigation), atmosphere, barrier free accessibility, safety, amenities (drinking water, restrooms, seating, shaded green spaces). Modern technologies can monitor continuously these services ensuring environmental sustainability, water efficiency, renewable energy, lighting, and biodiversity conservation (Itair et al., 2023).

As cities grow, planning and managing SUOS is essential to enhance QoL through harmonising social, cultural, and environmental dimensions (Yessoufou et al., 2020). The balanced SUOS provides socio-economic, ecological benefits while promoting healthy urban living and overall city well-being (Hameed, 2021). According to Polat and Alabbas (2018), certain key design principles play a vital role to create SUOS. The principles ensure SUOS design by considering the needs and preferences of diverse users to promote inclusive access, encourage fair distribution of resources and benefit in the community (Podvalny et al., 2021). Table 3 summarizes the design principles of SUOS.

As shown in Table 3, it can be posited that, when it comes to designing SUOS, there are certain design elements that contribute to its success. These design principles help creating spaces that are appealing, functional, and well-utilized by the community (Carmona, 2019). The SUOS design should be guided by the fundamental components of landscape character to achieve visual appeal. Integration of natural environment fosters tranquillity and encourages spontaneous interactions in SOUS (Lau et al., 2014). Table 4 lists the LDEs that makes an UOS sustainable.

In the light of the Table 4 it can be posited that the LDEs that combinedly help creating SUOS are numerous. SUOS plays a crucial role in the

Landscape design elements to create SUOS		
No	**Elements**	**Description**
1	Green Lawn	Poorly maintained green spaces can increase stress levels due to a sense of disorder and neglect (Ward Thompson et al., 2012)
2	Trees, Colourful and Dense Plantation	The presence of trees in SUOS can instantly become the main attraction, and the shade provided their huge canopies is the most appreciated aspect (Lau et al., 2014).
3	Circulation path	Circulation serves more than transportation; well-planned circulation paths can reduce noise and congestion (Lau et al., 2014).
4	Urban furniture	A successful SUOS must be equipped with street furniture that can influence users' attitudes and give them a unique experience (Sanei et al, 2017)
5	Water element/ blue space	Water features enhance beauty, promote human interactions, and provide cooling benefits, especially in hot regions (Salama, 2022).
6	Sculptures and landform	Placing sculptures in an open space attracts users and social interaction (Nikšič and Watson, 2018)
7	Safety and Security	Safe and secure environment is essential for the success of an open space. Adequate lighting, clear sightlines, and proper maintenance help promoting a sense of safety (Ruskin, 2018).
8	Comfort and Amenities	Amenities like seating areas, shaded spots, drinking fountains, public restrooms, and bicycle parking make the SUOS more inviting and convenient for users (Ruskin, 2018).
9	Flexibility and Adaptability	Successful open spaces are adaptable. They use movable furniture, multipurpose spaces, and modular structures to allow for flexibility in accommodating various needs (Zivkovic et al., 2019).
10	Smart Technology Integration	Smart technologies, like sensors, Internet of things (IoT) devices, monitor, and optimize resource usage enhance user experience, enable efficient maintenance and management (Soori et al., 2023).
11	Active and Passive Recreation	To satisfy user's diverse preferences the active and passive sports facilities, play areas, walking paths, and contemplative spaces could be provided (US Environmental Protection Agency, 2021).
12	Sustainable Construction and Materials surface	Using environmentally friendly and locally sourced materials in the construction, paving and maintenance of SUOS reduce carbon footprint, heat island effect and promote sustainability (Qiuli et al., 2017; Sankar Cheela et al., 2021).
13	Wayfinding system	Wayfinding system helps visitors navigate, understand the SUOS layout, reduce confusion and enhances the overall user experience by providing clear directions, signage, and information (Guida, 2015).

Table 4: Landscape design elements for SUOS. (2024)

liveability and sustainability of cities, particularly in hot and arid environments (Farjami and Taefnia, 2022). As global urban populations continue to grow, well-designed SUOS is essential. Urban planners must prioritize accessible green areas that promote community engagement and provide environmental benefits such as improved air quality, biodiversity preservation, and temperature regulation (Maes et al., 2019). Table 5 summarises the main criteria/conditions in designing SUOS.

It is observed in Table 5 that the conditions/criteria that combinedly help creating SUOS are numerous and related to diverse field of studies.

4. Framework formulation to understand the guidelines of designing smart-SUOS

Developing a design framework for Smart-SUOS is essential to improve QoL and fulfil the needs of the current urban residents and future generations. The framework integrates SOUS principles (Table 3), smart technologies (Figure 5), LDEs (Table 4), the conditions and criteria (Table 5).

Governance is the base of the proposed framework. Implementing policies aligning with sustainable principles and utilizing the communication layer disseminate the vital information. The physical layer serves as the foundation, which connects to sustainable sociocultural, economic, and environmental factors. It emphasizes the importance of users, facilities, and services incorporating sustainable design principles that prioritize environmental considerations such as microclimatic amelioration and the provision of ecosystem services. Furthermore, this layer addresses crucial economic factors, growth potential, cost-effectiveness, alongside socio-cultural aspects that encompass social inclusivity, and active community involvement. These principles are taken from the Table 3. Moreover, the SUOS design principles layers contain 13 LDEs and 10 DCs taken from Table 4 and Table 5.

The data collection layer supports the data collection, which gathers essential information to enhance the smart services layer. These services utilize the data processed by the server, ensuring efficient delivery by the communication layer and effective Smart-SUOS functionality.

The LDEs from Table 4 ensure the creation of functional and inviting spaces. Climate considerations drive the use of green lawns, dense plantations, and water features for natural cooling and shade. Culturally relevant sculptures enrich the open space identity, reflect local culture and enhance aesthetics. Sustainable construction materials ensure durability and environmental benefits, while street furniture offers shaded, comfortable resting areas. Smart technology integration enhances the UOS management and user interaction, while regular maintenance ensures longevity and cleanliness. Circulation paths improve connectivity, accessibility, facilitating

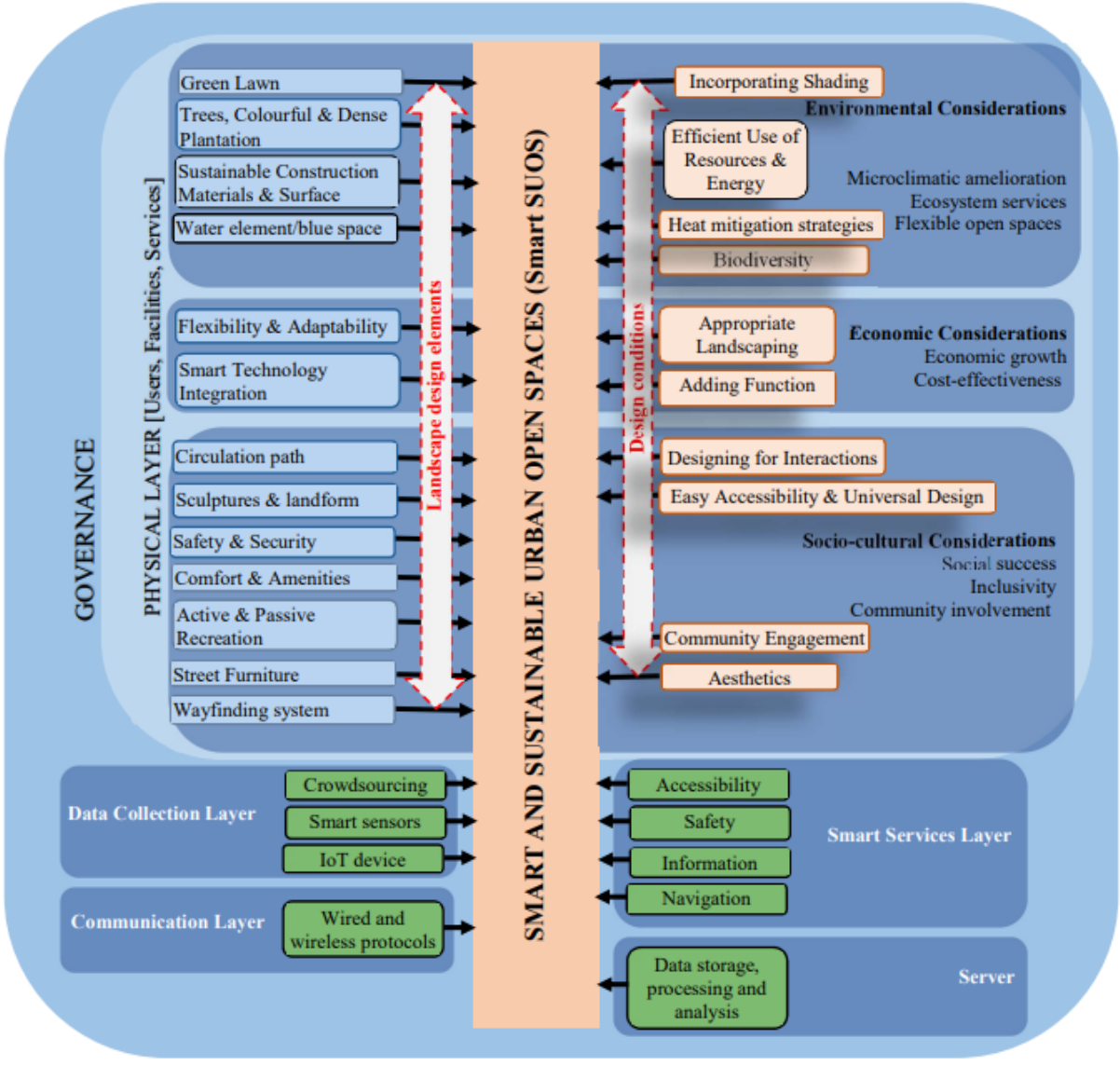

Figure 6: Framework (based on literature review) to understand the design guideline of Smart-SUOS. (2024)

		Conditions of designing suos
No	**Design conditions**	**Description**
1	Incorporating Shading	Shading elements, such as trees or pergolas reduce heat exposure and create inviting spaces (Turner et al., 2023).
2	Efficient use of resources and Energy	Efficient waste management systems like recycling facilities, smart bins, drip irrigation, low-flow sprinklers, moisture sensors, weather-based controllers for real-time weather conditions and waste reduction initiatives promote cleanliness and environmental sustainability (Esmaeilian et al., 2018; Bhavsar et al., 2023).
3	Heat mitigation strategies	Incorporating urban green areas and water features like fountains or misting systems would serve as an effective approach to mitigate the urban heat island effect (Aram et al., 2019; Langie et al., 2022).
4	Biodiversity	Incorporating native plant species, wildlife habitats, and preservation of existing natural features will enhance biodiversity (Threlfall et al., 2017).
5	Appropriate Landscaping	Choose heat-tolerant, drought-resistant native plants, requiring minimal water and maintenance that thrive in local conditions while enhancing aesthetic value (Threlfall et al., 2017).
6	Adding Function	UOS infrastructure can be categorized into three groups: open space for mobility, commerce, and recreation. Together, they create a dynamic environment for leisure activities and public interaction (Han et al., 2022).
7	Design for Interactions	Public spaces facilitate daily human activities, leading to diverse interactions between people and their surroundings (Alnaim and Noaime, 2023).
8	Easy Accessibility and Universal Design	For a public place to succeed, it should be easily accessible to all members of the community of all ages, abilities, and mobility levels, ensuring comfortable navigation (Persson et al., 2015; Esfandfard et al., 2018).
9	Community Engagement	Involving the community members through workshops, surveys, and public meetings in the design and planning process fosters a sense of ownership that meets their needs and desires (Sujatini, 2017).
10	Aesthetics	Aesthetics are crucial for successful UOS, as it enhance peoples experience, functionality, safety, engagement and enjoyment (Balasubramanian et al., 2022).

Table 5: Conditions of designing SUOS. (2024)

movement and social interaction. Safety and security measures ensure well-being in terms of health, a safe and inclusive space for all visitors. Simultaneously, these elements create a space that is not only resilient to climatic challenges but culturally resonant and user-friendly.

The design conditions of Smart-SUOS from Table 5 are intricately linked to environmental, economic and cultural factors. Incorporating shading and heat mitigation strategies is essential to create comfortable spaces, directly addressing the climate's challenges. Biodiversity and appropriate landscaping enhance ecological health, visual appeal and aesthetics. The efficient use of resources ensures environmental responsibility while adding functional elements support diverse activities and interactions. Culturally, SUOS must prioritize people's needs, fostering community engagement and a sense of belonging. Designing for interactions encourages socialization, community building, enhances user experience that respects cultural values. By synthesizing the SOUS principles (Table 3), smart technologies (Figure 5), LDEs (Table 4), along with the conditions and criteria (Table 5), a design framework is proposed as depicted in Figure 6. This consolidated framework aims to understand the guidelines of designing Smart-SUOS.

5. Validated framework to understand the guidelines of designing Smart-SUOS

The following Figure 7 presents the mean scores and RII values of the design elements, criteria, conditions for Smart-SUOS based on the data collected from questionnaire survey. This figure also highlights the significance (ranking) of each element in the design framework.

The survey analysis highlights the prioritization of social engagement, environmental comfort, and safety in the design of Smart-SUOS. The highest-ranked elements emphasize the significance of fostering community interaction and implementing climate resilience strategies. Additionally, accessibility to smart services and security measures are recognized as essential factors ensuring inclusive and interactive public spaces. Conversely, the least prioritized elements indicate a lower emphasis on technology-driven navigation, data management, and environmental diversity. The lowest-ranked element suggests that connectivity infrastructure is regarded as a supplementary rather than a primary design concern. Overall, the

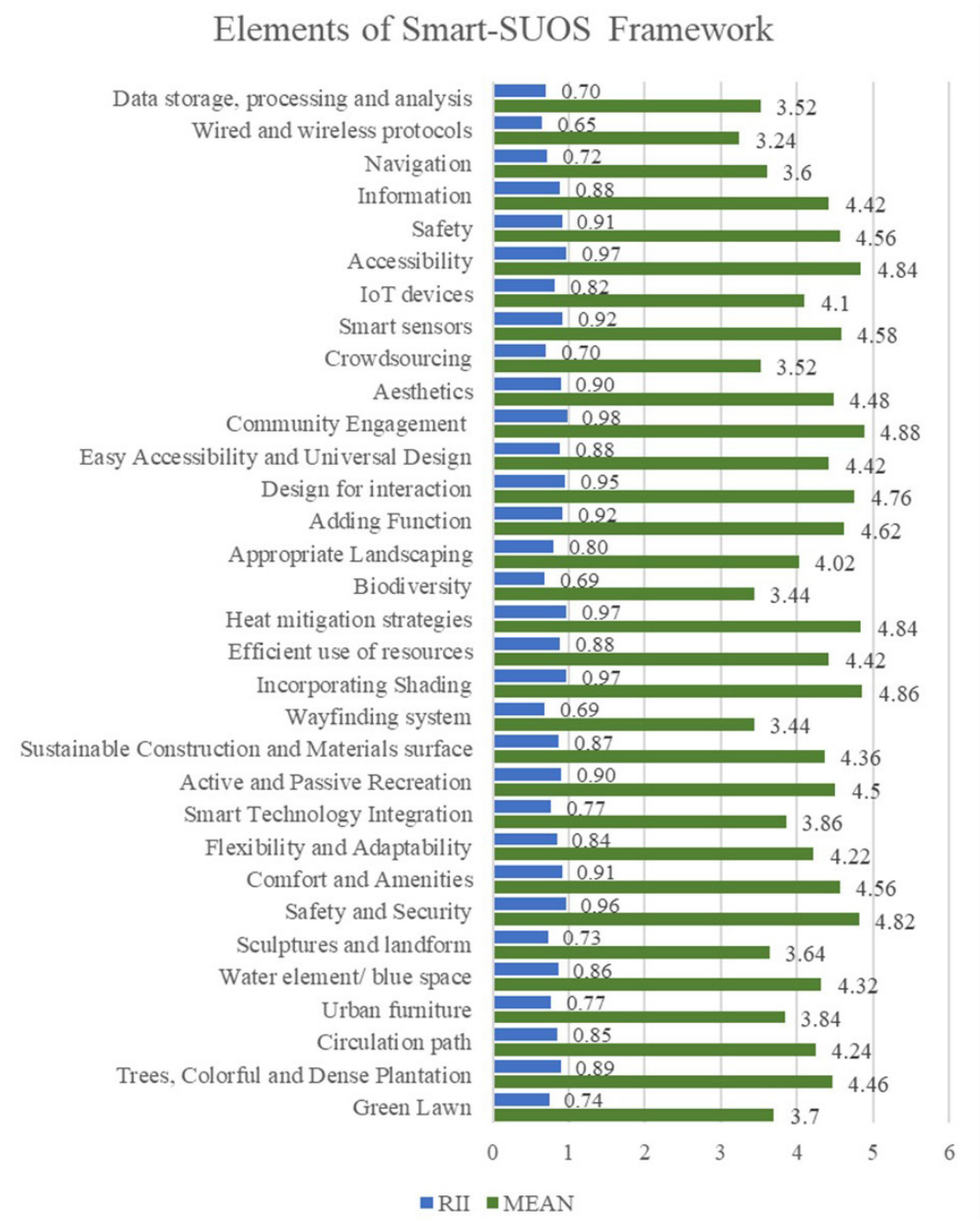

Figure 7: Analysis of Mean, ranking and RII of Smart-SUOS design framework elements. (2024)

findings underscore the necessity of balancing social, environmental, safety considerations while integrating technological and aesthetic enhancements in a supporting role within the broader design framework.

In the third section of the questionnaire, experts were asked to validate the framework (Figure 6) by providing critical insights for its enhancement. Figure 7 illustrates the reformulated, refined and validated design framework of Smart-SUOS.

Among the recommendations, experts suggested including "Thermal Comfort Elements" as an additional element under the LDEs. This addition encompasses cool pavements, misting systems, and reflective materials aimed at improving outdoor thermal comfort, particularly in the hot climates. Within the design conditions, experts emphasized the importance of "Cultural Heritage Integration" ensuring that the design reflects, preserves the historical and cultural context of the area. Additionally, the integration of "Renewable Energy Solutions" was proposed, involving the implementation of solar-powered lighting, smart grids, energy-efficient systems to enhance sustainability and reduce environmental impact.

Regarding Smart Services and Technology Integration, experts advised incorporating "Artificial Intelligence (AI) for Urban Management" to facilitate real-time monitoring of urban spaces, predict maintenance requirements, and optimize resource allocation. Furthermore, the inclusion of "Data Transparency" was recommended by the experts, advocating for secure and decentralized management of urban space data to enhance accountability and efficiency. The experts stated that all the design elements, criteria and conditions are interrelated. "Sustainable Construction Materials and Surface", "Water Element/Blue Space" and "Efficient Use of Resources and Energy", all are interrelated. The use of permeable pavements, recycled materials, and energy-efficient construction aligns with optimizing resource efficiency. This link ensures the sustainability of material use while reducing waste and carbon footprint. Water bodies such as ponds, fountains, and rain gardens help in stormwater management, groundwater recharge, and climate regulation. Linking these elements ensures better flood control, water conservation, and ecological balance.

"Smart Technology Integration" and "Renewable Energy Solutions" are interrelated. Integrating smart technology like smart lighting, automated irrigation, and energy-efficient infrastructure requires sustainable power sources. Ensuring smart technology with renewable energy solutions (e.g., solar-powered lighting, smart grids) guarantees energy efficiency, reduces dependency on non-renewable sources, and supports sustainable urban development. "Thermal Comfort Elements", "Heat Mitigation Strategies" and "Smart Sensors" are interrelated. Thermal comfort elements directly contribute to heat mitigation strategies by reducing the urban heat island effect and improving microclimatic conditions. Incorporating such elements ensure that SUOS remain comfortable, especially in hot climates, thereby enhancing usability, accessibility, and public well-being. Integrating smart sensors with heat mitigation strategies enhances the efficiency, adaptability, and sustainability of UOS. It enables a data-driven approach to manage heat stress, ensuring that interventions are responsive to real-time environmental conditions and improving urban liveability.

According to the experts, "Cultural Heritage Integration", "Community Engagement" and "AI for Urban Management" are interrelated. SUOS should reflect local identity, traditions, and cultural values. By linking Cultural Heritage Integration with Community Engagement, designers can safeguard the local communities to participate in shaping spaces that will reflect their history and cultural significance. Moreover, connecting Cultural Heritage Integration with Aesthetics ensures that cultural elements are not only functional but also visually appealing, fostering a sense of place and belonging. AI can analyse large datasets from community surveys, social media, and public forums to identify residents' priorities and concerns regarding SUOS. It can also predict the trends in community needs and spatial usage, allowing planners to proactively addressing emerging urban challenges. AI can process community feedback in real time by analysing comments, reviews, and social media discussions to gauge public sentiment about park conditions, accessibility, and amenities. This data-driven approach ensures that community concerns are quickly addressed, improving satisfaction and engagement.

Experts emphasized interrelationship between "Easy Accessibility" and "Crowdsourcing" because it ensures SUOS development based on user needs and real-time feedback. It promotes inclusivity, empowers communities, and helps planners create smarter, more accessible environments that genuinely serve all individuals. The interconnections between "Data Transparency", "Information" and "Safety" are essential for ensuring trust, security, and informed decision-making in Smart-SUOS. Transparent data management enhances public confidence, while well-structured information dissemination, safety measures contribute to more secure and efficient urban environments.

A number of experts stated a series of challenges and recommended several measures to be taken to overcome the challenges for the successful achievement of Smart-SUOS. The validated design framework in Figure 8 includes them accordingly.

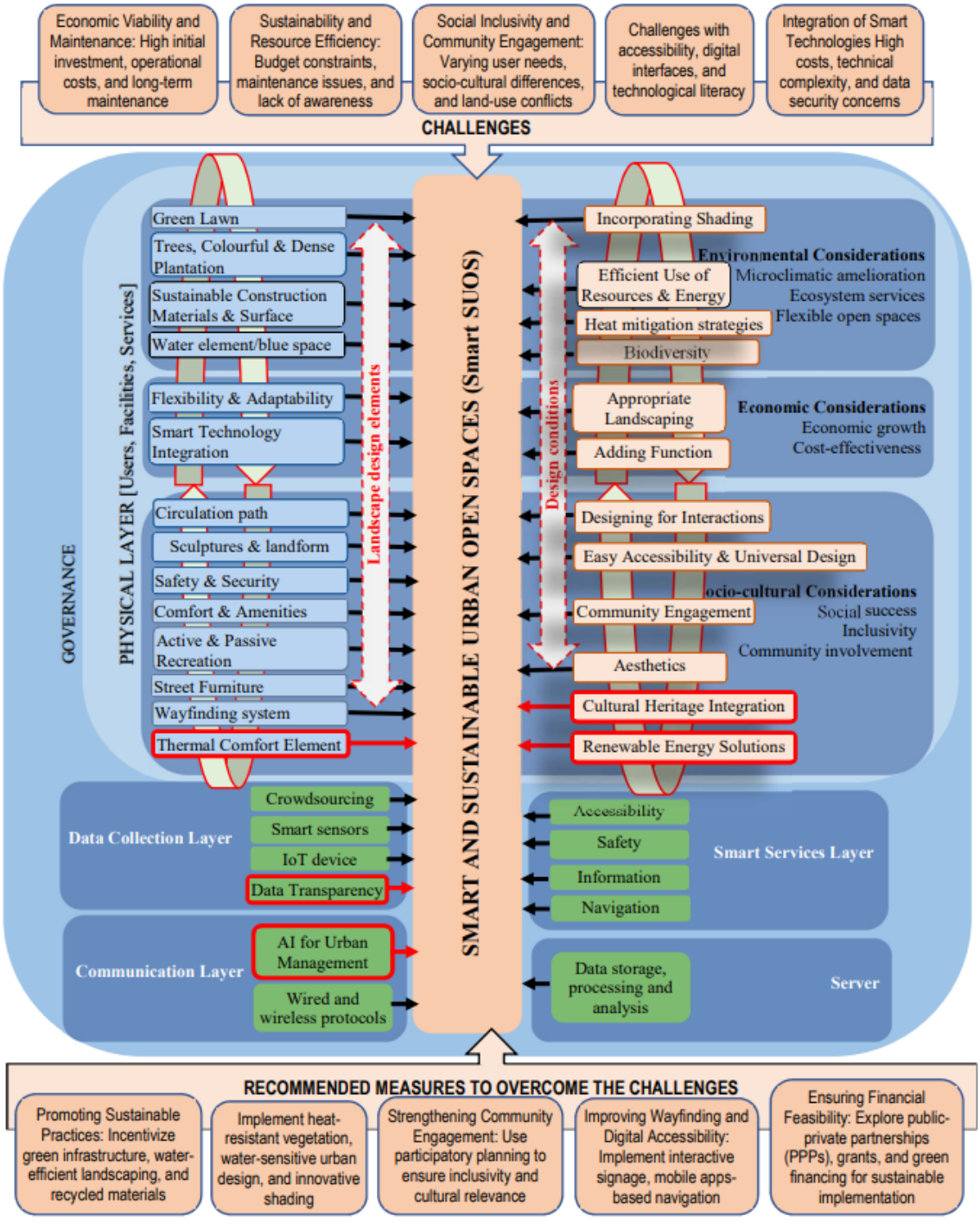

Figure 8: Validated framework (based on experts) to understand the design guidelines of Smart-SUOS. (2024)

6. Conclusions

This study highlighted the importance of Smart-SUOS in enhancing the urban QoL. By analysing essential design principles, landscape elements, criteria and conditions this study has provided valuable insights into the criteria necessary for designing environmentally-sound, socially-inclusive, and economically-viable Smart-SUOS. The design framework incorporated nature-based solutions, smart technologies, and universal accessibility practices that have worked to complement one another to maximize sustainability, liability, and community benefits. Drawing insights from the extensive literature review, this framework not only sheds light on the crucial design elements and criteria essential for creating Smart-SUOS but prescribed guidelines for urban planners and designers. The overarching goal of this study is to enrich the discourse surrounding the design of Smart- SUOS, offering a nuanced understanding of the intricate relationship between human activities, natural environment, and urban landscapes. By illuminating the path towards sustainable urban design, this framework aimed to elevate the QoL and enhance the overall well-being of urban environments. Through strategic guidance, urban stakeholders can harness the transformative power of sustainable design practices to create vibrant, resilient, and inclusive Smart-SUOS that stand as testaments to sustainable urban development.

Moving forward, it is recommended that further studies would focus on validating the challenges and measures to overcome the challenges for the successful achievement of Smart-SUOS. This could be through qualitative methods like case studies, interviews, field observations and quantitative method like questionnaire survey. Furthermore, exploring the impact of smart technology integration on the usability and sustainability of Smart-SUOS could also be a promising area for the future research.

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