

Using smart sustainable city indicators to evaluate urban quality in the Kingdom of Bahrain

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ABSTRACT

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The world continues to witness rapid urbanizations that induce environmental stress and urban challenges. Sustainable development policies were adopted globally to address such adversities, and investments in smart technologies to improve urban efficiency and quality of life are now a common theme. This research aims to define a Smart Sustainable City (SSC) within the local context, taking the Kingdom of Bahrain as a global case. The study further seeks to develop an assessment framework suitable for evaluating SSCs. Finally, the study validates the developed framework by quantitatively assessing the quality of urban life in Diyar Al Muharraq, a newly developed urban area in Bahrain, selected for its advertised goal of creating a smart and sustainable urban community. The research contributes to the understanding of SSCs globally. In addition, it creates a unique methodology for developing a local understanding and assessment framework for SSCs.

Keywords: smart sustainability; cities; indicators; evaluation; urban quality; bahrain

Introduction

Cities around the world have witnessed massive transformations due to the evolution of technology and globalization. The global shift towards urbanization has resulted in the transfer of mass migration towards cities. The urban population is expected to be 68 per cent in 2050, comprising 6.7 billion urban residents [1]. Urbanizing cities have played a significant role in economic growth and improving citizens' quality of life. The urbanization of cities has economically contributed 80% to the world's GDP. Moreover, the citizens' quality of life has been enhanced by providing employment opportunities, educational facilities, health benefits, reduced poverty, and improved living standards [2].

On the other hand, the development of cities and the accommodation of a growing number of citizens impacts the ecosystem drastically. Rapid urbanization has resulted in environmental stresses such as climate change, water scarcity, increased pollution, sea-level rise, extreme weather, and heat waves [3]. UN-Habitat (2016) described that the world's urban areas face more enormous problems than they faced twenty years ago. In addition, cities consume vast amounts of energy and generate a large amount of waste [4].



The Gulf Cooperation Council (GCC) cities have developed rapidly and witnessed urbanization in a short period. Economic development, global competitiveness, and improving the citizens' quality of life have been driving forces for urban growth. Moreover, the discovery of oil facilitated the massive urban development procedures in the Arabian Gulf. Since the mid-twentieth century, the development pattern in the Gulf cities has been attributed to the oil export economy [5]. As a result, the Gulf states witnessed significant changes in their Arabian urban context, such as rapid urbanization, increase in population, modernization, global cultural exchange, and socio-cultural transformation. Thus, the traditional indigenous societies were changed to advanced and motor-driven communities [6]. Though the Arabian Gulf consists of highly urbanized countries, the city management and sustainable development process are challenging. It is estimated that about 90% of the citizens will reside in the cities in 2050 in the Gulf countries [7]. Urban growth has improved the citizens' quality of life, but it has also imposed challenges and stressed natural resources.

To address the negative impacts of urbanization, the Kingdom of Bahrain acknowledged the Millennium Development Goals (MDGs) of 2000 and incorporated them into its development process. The Kingdom of Bahrain later adopted the Sustainable Development Goals (SDGs) plan established by the UN. The Kingdom of Bahrain addressed the SDGs by identifying them as a critical constituent of the national development agenda [8].

Moreover, the development of Information and Communication Technology (ICT) in recent years has made urban policies more techno oriented. Modern technologies have eased data sensing, communication, and urban computing [9]. Various steps are undertaken globally to adopt intelligent solutions for urban growth. One of the initiatives includes using ICTs in

urban development [10]. The Smart Sustainable City (SSC) concept aims at achieving sustainable goals by utilizing advanced ICT solutions. The idea of SSCs is a techno-urban process that addresses urban challenges and has become a growing trend since the 2010s [11].

The Kingdom of Bahrain has also adopted advanced ICTs in urban development. The technological development and the need to enhance the urban environment using smart solutions led to the establishment of the Bahrain Smart Cities Summit in 2016 [12]. Bahrain Smart City Society (BSCS) has also been established to highlight the importance of smart cities in the Kingdom of Bahrain. The government of the Kingdom of Bahrain has also adopted several measures to allow smart and sustainable development. Other measures include electronic financial transactions, healthcare appointments, billing, Tawassul (online complaint system), etc. Due to these efforts, the Kingdom of Bahrain was among the top 15 Asian countries with a high E-Government Development Index (EGDI) and ranked second among the six GCC countries [13]. Despite efforts towards smart and sustainable development, the roadmap to develop a SSC in the Kingdom of Bahrain is still not determined.

Assessing the policies adopted and implemented in the urban fabric is essential in SSCs development. The cities are complex and diverse. They contain multiple functions and allow varied activities for their citizens. The various aspects of a city, such as social, cultural, environmental, economic, and political, interact with one another and form the complex constituents of a city [14]. Therefore, there is a dire need to develop a methodology that can assist in assessing the policies implemented in urban areas. The assessment is a crucial factor as it analyses the effect of technologies and policies on the citizens' quality of life [15]. Urban planners have adopted the Key Performance Indicators (KPIs) to assess the impact of strategies and policies on the urban quality of cities. The KPIs facilitate

further understanding the city and its processes by monitoring the advancements and the effects of new urban strategies [16]. Analyzing the urban policies allows modifications to improve future policies and make amendments to the existing ones.

Key Performance Indicators (KPIs) are essential to assess and measure the development policies and actions and provide feedback for future developments. Unfortunately, a clear and concise strategy for developing SSCs and evaluating them using KPIs does not exist in the Kingdom of Bahrain. Although international organizations proposed many KPI standards, the need to possess a local framework exists. This research addresses smart, sustainable development in the Kingdom of Bahrain. Furthermore, it seeks to contribute by answering the following questions:

1. What are smart, sustainable cities according to the context of the Kingdom of Bahrain?
2. What are the Key Performance Indicators suitable to evaluate and assess the urbanism of the Kingdom of Bahrain?
3. Are the identified Key Performance Indicators suitable for measuring the urban development of the Kingdom of Bahrain?

Urban development in the GCC

The Arabian Gulf extends over the Arabian sea. It includes six countries: the Kingdom of Saudi Arabia, the State of Qatar, the United Arab Emirates, the Kingdom of Bahrain, the State of Kuwait, and the Sultanate of Oman. These countries form the Gulf Cooperation Council (GCC). The gulf region was historically nomadic and comprised almost 7.8 million people in the 1970s. The primary forms of occupation were trade and sea activities such as fishing and pearl diving [17].

However, the Arabian Gulf has undergone rapid urbanization after the discovery of oil. As a result, the

Arabian Gulf now hosts more than 40 million inhabitants in urban areas. The United Nations Statistics Division (UNSD) has described the reasons for the increase in population: migrations due to conflicts, international immigration, and a high human development index [18].

Al Mohannadi and Furlan [19] described that the evolution of the Gulf region's urban fabric could be divided into four phases.

1. Pre-oil phase: this phase is critical in the Gulf's history and creates the Gulf cities' character and identity. This phase includes the reliance upon the sea and its activities for livelihood and urban development. The houses had a courtyard and were inwardly oriented, providing privacy to the inhabitants and responding to the climatic conditions. Local techniques and materials were used for construction [5].
2. Modernization phase: this phase marks the transformation of traditional communities into modern ones using motor vehicles for transportation. This phase includes the advancement of infrastructure and urban development with the assistance of the British [19].
3. Oil prices inflation: this phase marks the rapid urbanization phase, which includes the development of massive road networks, governmental offices, modern buildings, etc. [6]
4. Globalization phase: this phase consists of developing planning practices and effective governance of planning procedures [20]. The globalization phase can be further divided into two phases:
 - a. The free trade zones and offshore banking during the 1980s and 90s.
 - b. Construction boom due to development visions and maintaining and promoting economic prosperity [19].

However, the current urbanization phase of the GCC countries is based upon the diversification of economies and shifting from an oil-dependent economy. Tourism activities, entrepreneurship, and other activities aim to diversify the economy and reduce dependence upon oil. In addition, there is a new wave of development in a knowledge-based economy. A knowledge-based economy aims to develop real estate by developing universities, research institutions, and hi-tech centres. Such an economy relies upon skilled and educated citizens to establish an environment of creativity and information sharing. Moreover, the Gulf countries have adopted sustainable development measures to combat the consequences of rapid development [21].

Initiatives adopted for the development of SSCs in the Arabian Gulf

Almost half of the world's population resides in cities, which is increasing daily. The growing challenges of climate change, population growth, CO₂ emissions, and resource depletion must be dealt with efficiently [22]. These challenges can be clearly witnessed in the GCC countries. They act as the forerunners while dealing with the increasing population of more than 30 times that of European Union countries and provide for their growing needs [23].

Smart sustainable urbanism has become an emerging trend in response to the growing urban challenges. It is a difficult task as the GCC countries rely heavily on cars as a means of transportation resulting in congestion, fragmentation of societies, and pollution [6]. However, the governing bodies are working towards solving these challenges as well. Some initiatives undertaken by the Kingdom of Bahrain include

improving the public transport system, air-conditioned bus stops for citizens, availability of taxis through online bookings or smartphone applications, and a proposed metro system in future development. One of the main challenges the Gulf region faces is the harsh climatic conditions. Due to the sweltering weather in summer and high humidity levels, pedestrian activity is challenging.

Moreover, urban planning in the Gulf region is derived from population growth, global competitiveness, and reliance upon international firms for urban plans [24]. The key challenges the Kingdom of Bahrain faces in sustainable development, as described in the VNR report (2018), include climate change, growing population, urbanization, lack of adequate land for growth, and degradation of natural resources.

The concept of SSCs

The concept of a smart city to achieve sustainability emerged due to the limitations of traditional approaches to making a city sustainable. The terms 'smart' and 'sustainable' are not mutually exclusive and target the same aspects of sustainable living. The term "smart sustainable city" emerged to include the aspect of sustainability in the smart city so that it is not ignored. The word "sustainability" was added to the "smart city" by the International Telecommunication Union (ITU) Focus Group. They initiated the term "smart sustainable cities" [22]. There are various existing definitions in the literature on SSCs. However, a single concise concept does not exist. The alterations occur due to the perspective and dimensions a researcher possesses. A common aspect of defining SSCs is that they intend to solve urban problems and improve citizens' quality of life while sustaining the natural environment [25]. SSCs contains the combined traits of smart and sustainable cities. Figure 1 demonstrates six main attributes of SSCs:

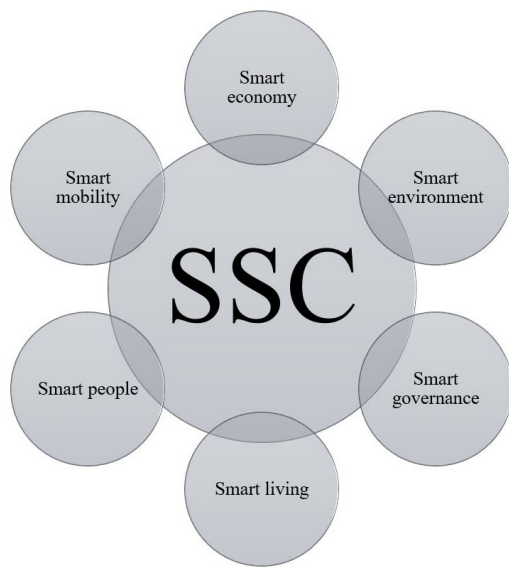


Figure 1. SSCs characteristics (Source: Adopted from [26]).

Developing a SSC is challenging, and several factors must be kept in mind during the transformation process. These factors include city context, city needs, local interest, willingness to change, adaptation by citizens, citizens' quality of life, and facilities provided to the citizens of a city. The process of transformation must be clearly defined before practising any action for efficiency. The transformation process can be demonstrated via the following:

- Roadmap- it consists of a diagrammatic illustration of the transformation phases. It must be clear, easy to understand, comprehensive and achievable [27]
- Framework- the framework defines the tools and other materials required to implement the roadmap phases [28]

Development of a Smart Sustainable City

SSCs development can be achieved by tackling two main aspects of an urban region.

- The tangible aspect includes the physical being of the city and is mainly concerned with the proper functioning of the city.

- The intangible aspect comprises immaterial elements and concerns the city's identity [29].

The development of a SSC requires the city to interact with and manage its resources. The components of SSCs have been divided into four layers. Three layers are vertical, and the fourth is horizontal. The vertical layers are oriented toward the physical dimensions of cities [30]. The first vertical layer states that a city becomes smarter when merging its built environment with the natural ecosystem [31]. For instance, the Kingdom of Bahrain thrives on economic growth without compromising its natural habitat. Strategies have been undertaken to allow development procedures while preserving environmental resources [32].

The second layer stresses that governance is crucial in developing smart cities. The responsible authority must arrange, manage, and provide effective administration and public services [33]. In the case of the Kingdom of Bahrain, the government aims to develop and diversify its private sector by increasing its participation in the economy [32]. As a result, new policies have been undertaken to boost innovation and entrepreneurship in the private sector. An example is the establishment of Tamkeen in 2006 as a national labour fund to develop the private sector. Tamkeen offers training programs, supports existing businesses and assists in creating new ventures [34].

The third layer is that the human and social capital generated must be divided and utilized within the city constituents [35]. Concerning the Kingdom of Bahrain, small-scale businesses play a vital role in the economy. Over 90% of the licensed firms in the Kingdom of Bahrain contain less than ten employees, and such businesses contribute to 30% of the GDP [36].

Finally, the horizontal layer is considered to possess modern and innovative technology, and it connects the three vertical layers to uplift the urban areas [37].

Thus, the smartness of the urban ecosystem is based upon the three fundamental pillars of social, economic, and environmental challenges.

Smart Sustainable City's Assessment

The analysis and evaluation of the city and its policies have become crucial in urban planning for the past few decades as the cities compete and aim toward global sustainability. The measurement practices allow the planners and others responsible for analyzing the impact of urban policies and help them make decisions. In addition, it allows the citizens and the city authorities to understand the effect of globalization on urban areas [38]. A practical measurement system must be developed that encompasses all the targets, be multi-dimensional, and does not focus on specific aspects while ignoring the other elements. [39] analyzed that sustainable city measurement systems are more inclined towards environmental issues. The smart city measurement systems focus on people and living. On the other hand, the competitive city measurement systems emphasize economic and business aspects. A common method of assessing cities' performance is using KPIs. These KPIs target and analyze multiple aspects of the city and allow a multi-dimensional analysis of a city [40]. The European Union (EU) promotes the development of SSCs and has developed various city initiatives [41].

Despite efforts to develop smart sustainable communities, the Kingdom of Bahrain does not possess a standard measurement system to assess smart sustainable urban quality. Nevertheless, the Kingdom of Bahrain has addressed sustainability and achieved 78% of the targets under the Government Action Plan. Some of the targets were excluded as they were not relevant to the context of the Kingdom of Bahrain, such as forest, rural development etc. The Kingdom of Bahrain has established 169 goals to achieve the 17

SDGs. To evaluate sustainable development progress, an international committee of interagency experts defined almost 232 indicators [42]. They assess the urban context based on the three pillars of sustainability, i.e., economic, social, and sustainable aspects every year [43]. Decree 21 was released in 2015, establishing the National Information Committee (NIC). NIC's responsibility was monitoring the indicators of sustainable development and coordinating and organizing data [44].

Moreover, an online portal has been developed in the Kingdom of Bahrain to pave the way for smart urbanism. However, the online portal consists of limited indicators. The other indicators are not found because they are either yet to be approved or are not provided by international organizations [42]. The identification of KPIs plays a vital role in the urban development strategy. KPIs are crucial for the following reasons [45]:

- they indicate accountability of procedures implemented using the public money
- they assist in the decision-making process
- they educate the citizens regarding the city activities
- they allow continuous development of city activities and betterment of its administration

Urban development strategies in the Kingdom of Bahrain

Due to the limited availability of land, the concentration of population and development are located mainly on the coastline. Therefore, the utilization of seafronts has induced stress upon the coastal lines and marine ecosystem. Additionally, the production of landfills, dredging, sewage treatments, desalination plants, plastic disposal, and waste excreted by factories induces pressure upon the marine ecosystem [43]. The Government of the Kingdom of Bahrain introduced vision 2030 in October 2008, aiming at

sustainable development and improving the living quality of the citizens [7]. After the launch of vision 2030, the authorities and the responsible bodies of the public and private sectors conducted discussions to implement and achieve the vision 2030 goals. The vision includes and addresses the sustainable development goals (SDGs) of 2030.

Bahrain Economic Vision 2030

The 2030 vision was based upon three main principles: competitiveness, justice, and sustainability seeking to develop and enhance the economy, governance, and society of the Kingdom of Bahrain [8]. The SDGs are implemented through the Government Plan of Action (GPA) with the combined efforts of the civil and private sectors. The GPA contains six main elements [42]:

- a. Enhancing security, stability, international relations, and a democratic system
- b. Establishing a stable financial system and developing a strong and variable economic system
- c. Facilitating the citizens to participate and contribute to the development process
- d. Providing infrastructure to allow sustainable development
- e. Efficient management of natural resources and promotion of sustainable urban development
- f. Refining the performance of the government

The vision 2030 aims to include the private sector in the development process as the government's budget has become limited and the economic challenges are increasing. Moreover, the vision states that the government will finance sustainable projects by implementing sustainability principles. The vision also aims at attracting new investors both at the local level and at the foreign level. Investors can be attracted by establishing high-quality industries, providing high-quality services, developing modern infrastructure,

and enhancing the natural environment [46].

Role of Public-private partnership (PPP)

The Kingdom of Bahrain aims to diversify its natural resource-based economy to a knowledge-based economy [32]. Vision 2030 laid the foundation to diversify the globally competitive economy, formed by the government and driven by the private sector. However, the private sector in the Kingdom of Bahrain had been relying on low waged workers, and the rate of innovation was negligible. As a result, the government aims to develop the private sector by strengthening the non-oil sectors such as tourism, business, and logistics [34]. A pilot study analyzing European cities demonstrated that increasing entrepreneurial activities and innovation are essential to compete in the global economic market. Thereby, European cities must enhance their innovative and creative aspects to develop entrepreneurial cities [47].

The Kingdom of Bahrain has developed several projects using the PPP model. The Electricity and Water Authority (EWA) implemented the PPP model in its projects. The Ministry of Works also adopted the PPP model to manage the wastewater and construct a sewage treatment plant in Muharraq. The Ministry of Housing has also undertaken the model in Northern City, Al-Lawzi, Diyar Al Muharraq etc. Future projects that are planned to be developed using the PPP model include a second causeway connecting Bahrain and Saudi Arabia. Moreover, a light rail scheme has also been devised to be developed in the future [48].

Role of ICTs in the development of SSCs in the Arabian Gulf

The Gulf region has recognized the importance of modern technology for developing SSCs. Therefore,

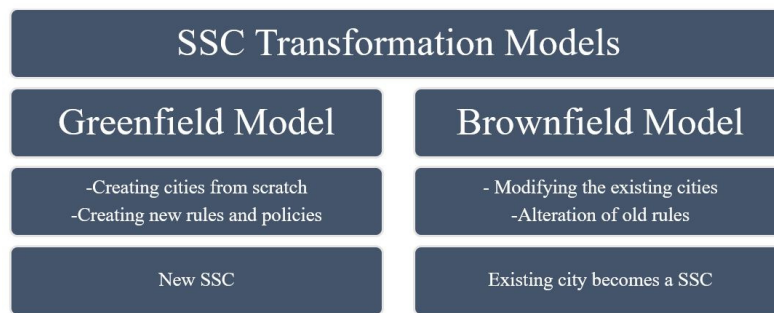


Figure 2. Greenfield VS Brownfield SSCs development framework (Source: Adopted from [49]).

initiatives have been undertaken to create large or medium-scale SSCs in the Arab region. These include the King Abdullah Economic City in Saudi Arabia, Qatar's Lusail City, Masdar City in the UAE, and Kuwait City in Kuwait. The transformation of a typical city to a SSC can be done according to the Greenfield or Brownfield models. The development of a SSC from scratch was termed as Greenfield model. Masdar City serves as an example of a Greenfield model. The modification and development performed to an existing city through policies, and other means were termed the Brownfield model, such as Amsterdam. The Greenfield model requires investments in new and advanced ICTs, and the Brownfield model requires modification and transformation of the existing ICT elements [49]. Figure 2 below illustrates the two SSCs, development models.

The Kingdom of Bahrain has applied both Greenfield and Brownfield frameworks depending on the circumstances to develop SSCs. For instance, the Brownfield framework was adopted in Manama to develop a SSC [50]. Moreover, many new urban development projects are being constructed in Bahrain, such as Diyar Al Bahrain, Dilmunia, Durrat Al Bahrain, Salman town, etc serve as an example for Brownfield model. These newly developed cities are built to be sustainable and target SDG goal 11 to 'develop inclusive, safe, resilient, and sustainable settlements.' The services provided in the newly developed projects aim to include modern housing,

developed infrastructure, efficient public amenities for citizens' needs, and a standard of living that is compatible with international norms. Other facilities include water availability, wastewater treatment, energy efficiency, renewable energy, advanced technology, and low-carbon development [43].

The Kingdom of Bahrain aims for urban development in the three pillars of sustainability, i.e., social, economic, and environmental [42]. Moreover, the Kingdom of Bahrain recently announced that it aims to reach net-zero carbon emissions by 2060. This initiative stresses the importance of enhancing green sectors and transforming global cities into sustainable areas to reduce the adverse impact on the environment. It also includes utilizing clean technologies and developing sustainable strategies [51].

Methodology

This research utilizes qualitative method of data collection in the initial phase followed by a detailed quantitative data analysis. The methodology adopted in this research for each objective is described below in Figure 3:

Defining a SSC according to the local context of the Kingdom of Bahrain

Various definitions are proposed for SSCs by multiple organizations, institutes, and academics. However,

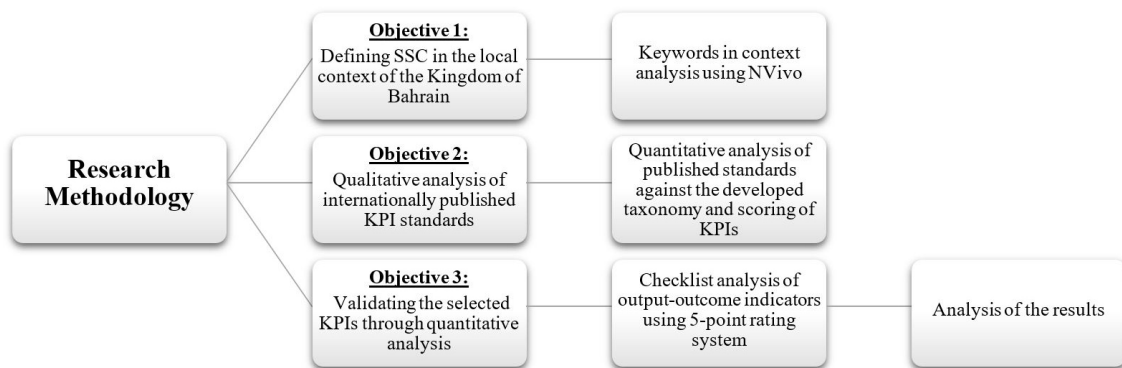


Figure 3. Research methodology (Source: Graphed by researchers).

there is no universally accepted definition worldwide that can be adopted for describing SSCs [52]. Therefore, this research aims to define a SSC in the local context of the Kingdom of Bahrain. The local context's methodology for determining a SSC includes qualitative data collection from pre-existing research, definitions, and publications. For this research, the following sources were referred to for information:

1. Academic journals
2. Government plans and documents
3. International publications and standards
4. Reports
5. Documents published by corporate organizations such as Arup and IBM

The urban development strategy of the Kingdom of Bahrain served as a guideline for the development of the definition. The Urban Planning and Development Authority (UPDA) (2021) of the Kingdom of Bahrain described that the Kingdom aims to

- Direct urban development to meet all the requirements and aspirations
- Establishing an urban future that enables economic growth and diversification according to the guidelines set in the National Detail Land Use Plan and the Economic Vision 2030
- Contribute to establishing sustainable urban communities
- Promote local urban culture and heritage

Keyword analysis was derived from the national urban planning plan and published international definitions. Mosannenzadeh and Vettorato [53] adopted keyword analysis for analyzing and defining smart cities. Kondepudi [54] applied the keyword methodology to define SSCs. More than a hundred definitions were analyzed, and the main keywords were extracted and tabulated according to their occurrence. The keywords were then divided thematically, such as environment, ICT, quality of life etc. Important terms were identified, and a final definition of a SSC was defined.

A similar approach of using keyword analysis was adopted in this research to define SSCs in the local context of the Kingdom of Bahrain. As stated in Vision 2030 of the Kingdom of Bahrain, the local aims and objectives of urban development are undertaken and analyzed along with the international definitions. A standard definition of SSCs in the context of the Kingdom of Bahrain was derived using the methodology of Kondepudi. This methodology is as follows:

- Literature defining SSCs was reviewed and documented.
- The data from the literature review was analyzed using keyword analysis using NVivo software version 20.6.1.1137.
- The keyword analysis results were compared to the national policies and strategies of the Kingdom of Bahrain.

- Keywords were then grouped into suitable categories adapted from the research of Kondepudi.
- The proposition of a definition is based on the above analysis.

Identify the KPIs that are suitable to evaluate the local urban quality of life

The second step is to identify a set of suitable KPIs to evaluate Bahrain's local urban quality of life. KPIs play a vital role in transforming and developing a SSC. They consider and assess the performance of cities and allow the comparison of the city's state at different intervals. Although the measurement and assessment of city performance are crucial in the city's development, a standard evaluation framework does not exist [55].

The methodology for identifying the KPIs framework to assess the urban quality of life was proposed by [56] and was also adopted by [57]. They conducted their research by selecting seven internationally published standards of indicators. However, for this

research, the selection of indicator standards was guided by the definition of the SSCs developed as a result of objective 1. Therefore, the definition of SSCs in the local context adopted in this study is as follows:

“A smart sustainable city in the Kingdom of Bahrain is a city that is developed through smart governance using sustainable measures and information and communication technologies (ICTs) to enhance the urban fabric, improve quality of life of citizens and boost economic growth.”

The definition mentioned above guided the selection of indicator standards for objective 2 of the research. Many governments at multiple levels such as city, national and inter-governmental are making efforts to implement these standards. The indicator framework ISO 37120 deals with the factor of quality of life. ISO 37122 measures the development of smart cities. The ITU-T KPI standards have been developed

Table 1. International standards analyzed for this research

KPI Standard	Description	Compliance with national policies	No. of indicators
ISO 37120: 2018a	KPIs for the performance of city services and quality of life	The Government Action Plan of 2019-2022 aims to develop city services such as education and health by investing in the citizens [58].	104
ISO 37122: 2019	KPIs for progress towards smart city	The Kingdom of Bahrain National Real Estate Plan 2021-2024 aims to develop smart and sustainable projects [59].	82
ETSI TS 103 463: 2017a	KPIs for improving digital multi-service cities	The Digital Government Strategy 2022 emphasized the commitment to digitalize services using emerging technologies to enhance the quality of life of residents and citizens [60].	76
ITU 4901: 2016b	KPIs for the use of ICTs in SSCs	The Kingdom of Bahrain strives to develop smart cities utilizing hi-tech and engineering solutions to improve socioeconomic conditions [60].	48
ITU 4902: 2016	KPIs for the impact of ICTs upon sustainability in SSCs		30
ITU 4903: 2016	KPIs for SSCs to evaluate SDGs	The SDGs form the core element of the Kingdom of Bahrain Economic Vision 2030 [46].	52
UN SDG 11+	Monitoring framework		18
Kingdom of Bahrain Urban Indicators: 2018	KPIs for the measurement of sustainability in the urban areas of the Kingdom of Bahrain	They were selected because of their local context to the region of study.	15
Total number of KPIs			425

Table 2. The selection criterion for KPIs in the Kingdom of Bahrain

Criteria	Description
Relevance	The indicator must be important for the evaluation and strongly connected with the subthemes.
Reliability	The indicators must be clearly defined and not be open to multiple interpretations. The measurement methods of the indicators must be clearly defined.
Data availability	The data for the indicators must be readily available. It can be derived from public sources, interviews, observations, project leaders, etc.
Measurability	The indicators should be measurable quantitatively, qualitatively, and descriptively.
Alignment	The indicators must align with the purpose and aim of implementing the smart city pilot.
Independence	Changes in the measurement of an indicator must not impact the other indicators in evaluation.
Familiarity	The indicators must be easy to understand for its users.
Non-redundancy	The indicators in a framework must not measure the same aspects in the sub-themes.

Indicator	Urban focus	Sustainability
		Smartness
	Indicator type	Input, Process, Output, Outcome, Impact
	City sector	Natural environment, built environment, water & waste, transport, energy, economy, education, culture, innovation & science, health, well-being & safety, governance & citizen engagement, ICT

Figure 4. Greenfield VS Brownfield SSCs development framework (Source: Adopted from [56]).

jointly by ISO and UN agencies [39]. ETSI, ITU 4901, and ITU 4902 estimate the performance of ICTs in security, sustainability, and city services. Moreover, ITU 4903 and UN SDG+ evaluate a city's sustainability aspects. In addition to these international frameworks, the Kingdom of Bahrain's urban indicators framework was also selected because it is more relevant to the local context. This framework measures the sustainable aspects of a metropolitan area. The KPIs selected for this study are the latest versions of the international standards KPIs released. Table 1 illustrates the international standards undertaken for this research and the reason for their selection.

A qualitative analysis of the KPIs identified from the international standards mentioned in Table 1 was conducted against general criteria. It allows the

analysis and removal of indicators that do not comply with these criteria. Many researchers proposed the following criteria: CIVITAS, CITY keys, IRIS, [57], [55] and [39]. As the requirements developed are general, they can also be implemented in the local context of the Kingdom of Bahrain. The selection criterion of KPIs is demonstrated in Table 2.

The filtered KPIs are then scored quantitatively against a taxonomy developed based on the goals and targets set for a SSC. Therefore, the analysis and scoring of the urban indicators are crucial for adequately selecting KPIs [61].

Taxonomy for indicator analysis

A uniform taxonomy was developed, and the selected KPIs were analyzed against it. The taxonomy

for analyzing indicators comprises three main factors: urban focus, type of indicators, and city sector [56]. Figure 4 illustrates the taxonomy:

Urban focus

The first factor of taxonomy is the urban focus, which focuses on the city's smartness and sustainability goals. Smartness refers to the application ICTs and other smart solutions implemented to enhance the city's performance. The smartness of a city can be divided into hard and soft. In comparison, sustainability refers to the optimal usage of resources and protection of the environment to allow future generations to meet their own needs. Sustainability has three core aspects, i.e., social, economic, and environmental. Therefore, the selected KPIs were based on the triple bottom line approach, including environment, economy, and society [62].

Indicator Types

The measurement of the city's progress is a process that is evaluated at different time intervals. Therefore, it is appropriate to use the input-process-output-outcome-impact model to evaluate cities. This method has been adopted by the UN as well. This model is efficient for city monitoring processes as it can evaluate the city's performance at different phases of development. It also assesses the impact of policies on the city that appear later in the development phase. As the impact indicator measures the city's performance in the later years, the output and outcome indicators are used to report the city's performance in the short term.

City Sectors

The classification of identified city sectors was developed based on the research of [61] and [63]. The exact classification of city sectors was implemented in

this research as they align with the urban development of the Kingdom of Bahrain.

Scoring of KPIs Against the Taxonomy

The analysis and scoring of the KPIs of the study frameworks against the taxonomy factors: city sectors, indicator type, and urban focus were performed. The KPIs were scored with the distribution of points in each taxonomical category. For example, the city sector category was given two points. The indicator type category was given one point. Three points were given to the urban focus category, i.e., smartness and sustainability. The sustainability factor was further divided into people, planet, and prosperity to identify which aspect of sustainability the indicator fulfilled.

Similarly, the smartness factor was classified into hard and soft smartness to determine the indicator's smartness type. The scores were then summed up, and percentages of each indicator sum according to the category were deduced. This scoring procedure was proposed by [61] and was adopted by [56] in their research for indicator analysis.

Validation of the Selected KPIs

The final step is to validate the test results of the selected KPIs. A checklist analysis was adopted to evaluate and assess the urban quality of life in Diyar Al Muharraq. The output and outcome indicators were selected to perform the checklist analysis of the urban quality of life in Diyar Al Muharraq. The impact indicators were not undertaken for checklist analysis as Diyar Al Muharraq is a recent project, and its first development phase was expected to be completed in 2018 [64]. Therefore, it is appropriate to perform analysis using the output-outcome indicators because Diyar Al Muharraq is a newly developing project with some phases still under construction. Impact indicators were not used as they can be utilized for analysis of

urban quality of life after the project has been implemented and is in full use [65]. This is because the project's impact becomes apparent after years, and the process is slow [65]. The output indicators measure the details of the product, and the outcome indicators measure the intermediate effects of the project [65].

The evaluation of the urban quality of life against the KPIs can be conducted through a checklist, questionnaire, or scoresheet [66]. The questionnaire methodology could not be implemented in this research as the administrative authority of Diyar Al Muharraq had reservations about the distribution of external surveys. A checklist was prepared for this study, containing the output and outcome indicators. These indicators were used to analyze the multiple features of the urban spaces, such as accessibility, safety, health, education etc. The indicators were assessed on a 5-point scale, as Garau and Pavan [55] adopted in their research. The rating scale was termed as such due to the maximum score of 5 on the scale. The rating scale was set as follows:

- 0 points for insufficient assessment
- 2 points for sufficient assessment
- 4 points for a good assessment
- 5 points for the excellent assessment

The checklist analysis was performed by Garau and Pavan to analyze Cagliari's context in Italy critically. An in-situ analysis of Cagliari was conducted to collect data and photographic documentation. The indicators were assessed through graphs and information sheets containing tables describing the area's conditions. This analysis procedure was developed to allow a numerical analysis of the urban factors. It allowed a detailed overview of each urban quality. It enabled the researchers to assess the efficiency and deficiency of the elements in the master plan. For this research, the researcher adopted and filled the checklist analysis through observations by

site visits, online publications, Diyar Al Muharraq press releases, and interviews.

Diyar Al Muharraq as Case Study

The selected KPIs are used to evaluate the quality of life in an urban area in the Kingdom of Bahrain to test the efficiency of the selected indicators. Diyar Al Muharraq was chosen for the analysis of the selected KPI. It is a recent urban development created with advanced techniques and strategies.

1. Diyar Al Muharraq has been an active member contributing to developing smart cities in the Kingdom of Bahrain. It is a platinum sponsor of the Bahrain Smart Cities Summit [67].
2. Diyar Al Muharraq has been designed with sustainability at its core as its main pillar. It has been implemented in various aspects of the master plan for social, economic, and environmental factors [68].
3. The real estate properties have been sold and occupied by owners. Thereby, their experience can contribute to the research.
4. It was described that almost 4000-10,000 inhabitants are considered optimum for evaluating an urban area [69]. In contrast, Diyar Al Muharraq is a massive community that will house over 120,000 people upon completion [70].
5. It is a community that has been designed to contain mixed spaces to preserve heritage and provide a modern lifestyle to the citizens.
6. Green solutions and smart technologies have been implemented in urban development and housing units to reduce carbon footprint [68].

Therefore, Diyar Al Muharraq served as a representative case for analyzing recent and future urban developments in Bahrain, as it is designed to be an advanced and multifaceted city that helps its users and visitors.

Results

The results from the methodology described above are outlined in reference to the research objectives. They are as follows:

Objective 1: Defining SSCs in the Kingdom of Bahrain

The keywords analysis of the definitions demonstrated that the term ‘sustainable’ was the most occurring keyword. The next keyword with the maximum number of occurrences was found to be ‘quality of life’. The other keywords include ICT, economic, urban, environment, quality of life, and development. However, the keywords having the lowest occurrences were public, innovation, mobility, transport, building, and education.

The keywords were then categorized into seven categories: smart living, smart economy, smart governance, smart people, smart environment, and smart mobility. The different categories, subcategories, and their respective keywords have been colour coded and presented in tabular form. Table 3 below demonstrates the categories, subcategories, and the percentage of occurrence of keywords.

The grouping of keywords derived from international definitions into respective categories demonstrated that smart environments had the highest percentage. Followed by smart living and smart people. It can be deduced from the analysis that most

international definitions aim to preserve environmental resources, improve the quality of life, and engage citizens in the development process. The least percentage was found to be of smart governance and smart economy.

The results obtained from the keyword analysis were compared to the policies and goals of the Kingdom of Bahrain to define a SSC in the local context. As a result, the following definition of a SSC was deduced and was also adopted in this study:

“A smart sustainable city in the Kingdom of Bahrain is a city that is developed through smart governance using sustainable measures and ICTs to enhance the urban environment, improve quality of life and boost economic growth.”

Objective 2: Identifying KPIs that are suitable to evaluate the local urban quality of life:

The analysis of the KPI frameworks against the city sector taxonomy demonstrates that the selected indicator frameworks mainly target a city’s health, well-being, safety, ICT, water, and waste factors. The minimum number of indicators were found for the built environment and energy sectors. However, the economy was also an important factor in the city sector. Therefore, it can be deduced that most of the indicators are inclined to improve citizens’ quality of life by focusing on healthcare facilities, the safety of the citizens and their data, waste management, water

Table 3. Groupings of keywords into categories

Category	Subcategory	Percentage
Smart living	Quality of life, ICT, communication, intelligence, information	7
Smart economy	Economy and finance	2.6
Smart governance	Governance, management, and administration	2.3
Smart people	People, citizens, society	4.4
Smart environment	Environment and sustainability	7.4
Smart mobility	Mobility, infrastructure, and services	3.0

services, and smart solutions to enhance the efficiency of the urban environment. It can also be seen that most urban indicators in the Kingdom of Bahrain address governance, citizen engagement, and the economy. This demonstrates that the Kingdom of Bahrain is making efforts to transform itself into a smart and sustainable one. Nevertheless, the local indicator framework lacks indicators for assessing ICTs, education, culture, innovation, transport, and energy. This indicates that the Kingdom of Bahrain lacks a standard indicator framework to evaluate urban smartness and quality of life.

The analysis of the selected KPI frameworks against the category of indicator type shows that the maximum number of indicators are output indicators, followed by impact and outcome indicators. These indicators analyze the aftereffect of the policies and strategies implemented. They measure the effectiveness of ICT solutions and provide feedback about their achievements or shortcomings. Thereby, they are crucial for the analysis of an urban area.

The results from the analysis against the urban focus illustrated that the sustainability indicators are higher in number than the smartness indicators. Moreover, the urban indicators in the Kingdom of Bahrain mainly targeted sustainability to achieve the UN sustainability goals.

Objective 3: Validation of the selected KPIs:

The results obtained from the checklist evaluation of Diyar Al Muharraq suggested that the selected KPIs framework could assess multiple factors of the city quantitatively. However, the output and outcome indicators used in the analysis did not consider some environmental factors, such as hot climatic conditions and sea-level rise, relevant to the Kingdom of Bahrain. The analysis of Diyar Al Muharraq can be compared to the five key drivers presented by JESSICA (2012) to develop a SSC. These are as follows:

- i. A city's increase in size and density requires improved infrastructure to provide efficient delivery services. Diyar Al Muharraq is a recent development, and all its infrastructure is newly constructed. Thereby, it can accommodate efficient delivery services.
- ii. The establishment of new retails solves city challenges and enhances city development. Diyar Al Muharraq was developed as a mixed-used city. As a result, 8.75% of the land was allocated for economic activities.
- iii. Renewable and efficient energy resources must be utilized for infrastructure and residential purposes. This factor needs to be developed in Diyar Al Muharraq as the energy used in the city services is derived mainly from fossil fuels. Thereby, other means of energy sources must be tested and utilized.
- iv. Reduction in carbon emissions must be committed. Some initiatives have been undertaken in Diyar Al Muharraq to reduce the carbon footprint. These include reducing the use of passive transport, recycling wastewater, solar trees, providing electric vehicle charging stations etc.
- v. Implementation of sensors and intelligent solutions to ease urban processes. Implementing ICTs is a general practice in Bahrain and is not limited to Diyar Al Muharraq. The urban ICTs installed are speed sensors, cameras, smart traffic lights, smart meters, scanning measures, etc.

The total number of output and outcome indicators used for analysis is 565. The study of Diyar Al Muharraq resulted in 418 scores. This constitutes 73.9% of conformity to the selected output and outcome indicators. The results demonstrate that Diyar Al Muharraq can be developed as a SSC. However, some factors need to be improved, most of which are efficient energy sources.

SSC in the Kingdom of Bahrain challenges and opportunities:

The Kingdom of Bahrain has undergone rapid urbanization which on one hand has improved the lifestyle of its citizens. On the other hand, it has imposed multiple urban, social, and environmental challenges upon the Kingdom. The Kingdom like the other countries of the Arabian Gulf face challenges due to multiculturalism, urban sprawl, gentrification, and gated communities. The concept of sustainability and smart city is a recent concept in the Kingdom of Bahrain. Whereas the concept and its implementation has evolved gradually in the West through a long-term process, the Gulf has experienced instant urbanism. The most notable among the challenges the Kingdom of Bahrain face is the vast immigration of expat population attracted by economic stability and other opportunities. This has resulted in segmentation, social differentiation, and gated communities [71]. Moreover, the availability of wealth had caused the development of modern buildings and mega projects that replicate the Western styles. Due to this the Kingdom of Bahrain suffer from traffic congestions, real estate inflation, detrimental environmental effects, etc [6]. In addition to that the climatic conditions of the Gulf region are very harsh and limit the passive mobility modes. Thereby contributing to increased traffic jams and congestions. Another challenge the Kingdom of Bahrain faces is the shortage of land for the urban projects. A common practice to solve this issue is land reclamation which adds more cost to the project and threaten marine life.

The Government has undertaken multiple initiatives to tackle the challenges and promote smart and sustainable development. These include adaptation of ICTs in the urban regulatory practices, such as smart traffic control, smart cooling infrastructure, smart banking, adoption of AI, promotion of Cloud com-

puting, etc [72]. The aim for economic diversification has advanced new industrial zones, research and knowledge-based cities, smart technologies, smart urban spaces, and planned division of urban areas. In addition to that the housing minister in the Kingdom of Bahrain announced that the new urban projects will be developed based on smartness and sustainability. This includes providing open public spaces, proper landscape along the streets, smart technologies, use of local materials and cultural integrity. The goal of SSCs can be accomplished by introducing innovative solutions to urban problems and by utilizing the human capital [73]. Social inclusion plays an important role in the development of SSCs. The Kingdom of Bahrain is addressing its infrastructure demands due to the development of new projects and increased population. Several projects for the expansion of roads and construction of flyovers are undertaken. The Public-Private Partnership has also been strengthened to allow more stakeholders to participate in the transformation process. Despite the measures undertaken by the Government the Kingdom of Bahrain requires an effective regulation and measurement standards to develop and implement SSCs solutions throughout the Kingdom.

Research limitations

- COVID-19 restrictions: This research was conducted during the outbreak of the COVID-19 virus, which restricted physical meetings and face-to-face interviews. Social distancing served as a setback for data collection procedures.
- Availability of data: The Kingdom of Bahrain lacks a proper data-sharing accessibility platform. Therefore, this was a significant constraint in data collection procedures.
- Restricted access to communities: Gated communities such as Diyar Al Muharraq are

challenging to access for data collection and assessment. The administration of urban development maintains strict privacy policies.

- Citizens' participation plays a vital role in the development of SSCs. Thereby, future research can evaluate citizens' perceptions and assess their feedback. In addition to that, the experience of the citizens can be evaluated.

Conclusion

The deteriorating environmental impact caused by globalization and the quick massive construction trends stimulated a global discussion on smart sustainability. The Kingdom of Bahrain faces enormous urban challenges due to its small size and scarcity of natural resources and the hot and humid climatic conditions that stress the energy sector. Consequently, the Kingdom of Bahrain adopted several measures for sustainable development and prioritized using advanced technologies to improve urban life. Nonetheless, like many countries, there is not yet an accepted definition of a SSC in the local context, nor is there a standard assessment framework that evaluates SSCs locally.

This research fills the gap in the literature by defining and identifying the key principles of a SSC in Bahrain. The keyword analysis depicted that the definitions of the SSCs mainly consist of 'smart environment' and 'smart living' as the prime concepts. The Kingdom of Bahrain aims to adopt ICT solutions to enhance the quality of urban life further and diversify the economy, sustain environmental resources, and develop smart citizens. In addition, the Kingdom thrives on economic growth to maintain global competitiveness. This can be achieved through smart governance and Public-Private Partnerships (PPPs).

An assessment methodology is presented in this study to evaluate the quality of urban life using a set of KPIs. The analysis of the multiple frameworks of KPIs

showed that the indicators mainly target to improve the citizens' quality of life. The next factor upon which the indicators focussed was ICTs which form a crucial factor in developing SSCs, followed by water and waste management. The KPIs analysis also showed that the KPIs framework must be modified and revised to suit the city's local context. For instance, some of the indicators that did not apply to the Kingdom of Bahrain were removed in this research, such as natural disaster management and freight movements. In comparison, some indicators were not included in the output and outcome category, even though they are essential for the local context of the Kingdom of Bahrain. These include KPIs dealing with harsh climatic conditions, sea-level rise, water salinity, and shortage of land area. Developing an efficient framework of KPIs beforehand is crucial as cities around the world aim to develop in a smart sustainable manner.

Finally, the research validates the selected framework by assessing the quality of urban life in Diyar Al Muharraq. The checklist analysis demonstrated that Diyar Al Muharraq is striving to become a SSC. However, some factors need improvement, such as waste recycling, providing shade to public areas, improving online services etc. Diyar Al Muharraq is a recent project, and many aspects of the city are yet to be analyzed and assessed. Educational, entertainment, and health facilities are still about to open in Diyar Al Muharraq. Thus, any analysis conducted in the coming years can generate different results than this study.

The main setback faced by the researchers while conducting this study was the COVID-19 restrictions. Limited access to local data and gated communities restricted the accessibility to residents and data collection procedures. Nevertheless, future studies can be conducted to determine the impact of the urban strategies implemented in Diyar Al Muharraq.

The citizens play a crucial role in urban develop-

ment. Future works can be conducted to assess citizens' perceptions regarding the urban quality of life. Another aspect that can be interesting to study is the alterations in Diyar Al Muharraq that may or may not align with the planning strategies. This research has proposed a methodology to evaluate the urban quality of life in the Kingdom of Bahrain. The developed methodology can be tested upon other urban developments. As the Kingdom of Bahrain aspires to develop smartly and sustainably, having an evaluation framework available at an early stage is crucial.

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