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# A case study on the barriers towards achieving sustainable smart city for Abu Dhabi

Rahaf Ajaj[1] | Mohanad Kamil Buniya[2,3] | Ibrahim Yahaya Wuni[4] | Omar Sedeeq Yousif[5]

[1]Department of Environmental and Public Health, College of Health Sciences, Abu Dhabi University, Abu Dhabi, United Arab Emirates

[2]Department of Civil and Environmental Engineering, University Technology Petronas, Seri Iskandar, Perak, Malaysia

[3]Department of Civil Engineering, Al-Maarif University College, Anbar City, Iraq

[4]Department of Architectural Engineering and Construction Management, King Fahd University of Petroleum and Minerals, Dhahran, Eastern Province, Saudi Arabia

[5]Faculty of Civil Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

**Correspondence**

Rahaf Ajaj.
Email: rahaf.ajaj@adu.ac.ae

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## Abstract

Developing sustainable smart cities (SSCs) is crucial to modern urban growth, as recognised in various international policies and literature. With Abu Dhabi as a focus, this research aims to identify and evaluate the primary obstacles that hinder the creation of intelligent and sustainable cities. By categorising and ranking these barriers, the study seeks to prioritise the most significant hindrances to smart city development. The research analysed 31 barriers, classified them into six groups, and examined them through existing literature. Semi-structured interviews with stakeholders responsible for implementing the SSC strategy provided additional valuable insights. The study used the Partial Least Squares Path Modelling method to prioritise the selected barriers. The results showed that the most significant barriers to SSC development were in the Economic category, followed by Technology, Governance, Social, Legal, Ethical, and Environmental barriers. This research provides valuable insights for policymakers and the Abu Dhabi government to eliminate obstacles that hinder SSC development initiatives.

**KEYWORDS**

city brain and smart cities metrics, city design, governance, planning & policy, city indexes, metrics, comparisons, and rankings, smart cities, smart cities standards

## 1 | INTRODUCTION

In the last two decades, the concept of smart city (SC) has gained increasing attention in academic research and international politics. Cities play a crucial role in shaping the future, and it is essential to comprehend and analyse their development. Cities significantly impact the environment and are crucial to global social and economic progress [1]. As per the United Nations (UN) report, over 3.3 billion individuals, that is, more than half of the world's population, resided in urban areas in 2008. The projections indicate that this percentage will rise to 70% by 2050. The emergence of megacities with populations surpassing 20 million people in Latin America, Africa, and Asia underlines the global importance of cities [2].

The United Arab Emirates (UAE) population is 10.4 million in 2024, up 0.79% from 2023. 9.11 million people, or 87.6% of the country's population, live in the UAE's metropolitan areas [3]. According to official data from the Dubai Government, the UAE has a population density of 121.59 people per square kilometre, with most people residing in Abu Dhabi and Dubai. The Abu Dhabi Emirate has a much higher density of 1900 people per square kilometre. As of 2023, the

Abu Dhabi Emirate has a population of 2.9 million, of which Abu Dhabi city is predicted to have 1.566 million residents. Figure 1 shown the UAE and Abu Dhabi maps. Abu Dhabi's population increased by 27,169 people over the previous year, a yearly increase of 1.76%–2.2% [6]. These projections and estimations are based on the current UN World Urbanisation Prospects study [7].

As urban centres expand, their resource consumption and environmental impact are escalating. UN-Habitat reports that cities utilise 78% of the world's energy and contribute over 60% of carbon emissions. The higher the population density of an urban area, the more energy is necessary for transportation and other necessities [8]. Cities often generate waste and use products with negative externalities, worsening social and economic issues. Increasing natural resource reserves can improve sustainability [9]. This perspective holds that cities must deal with social and economic problems sustainably.

Cities worldwide seek ways to adapt to the current environment and promote economic growth through improved

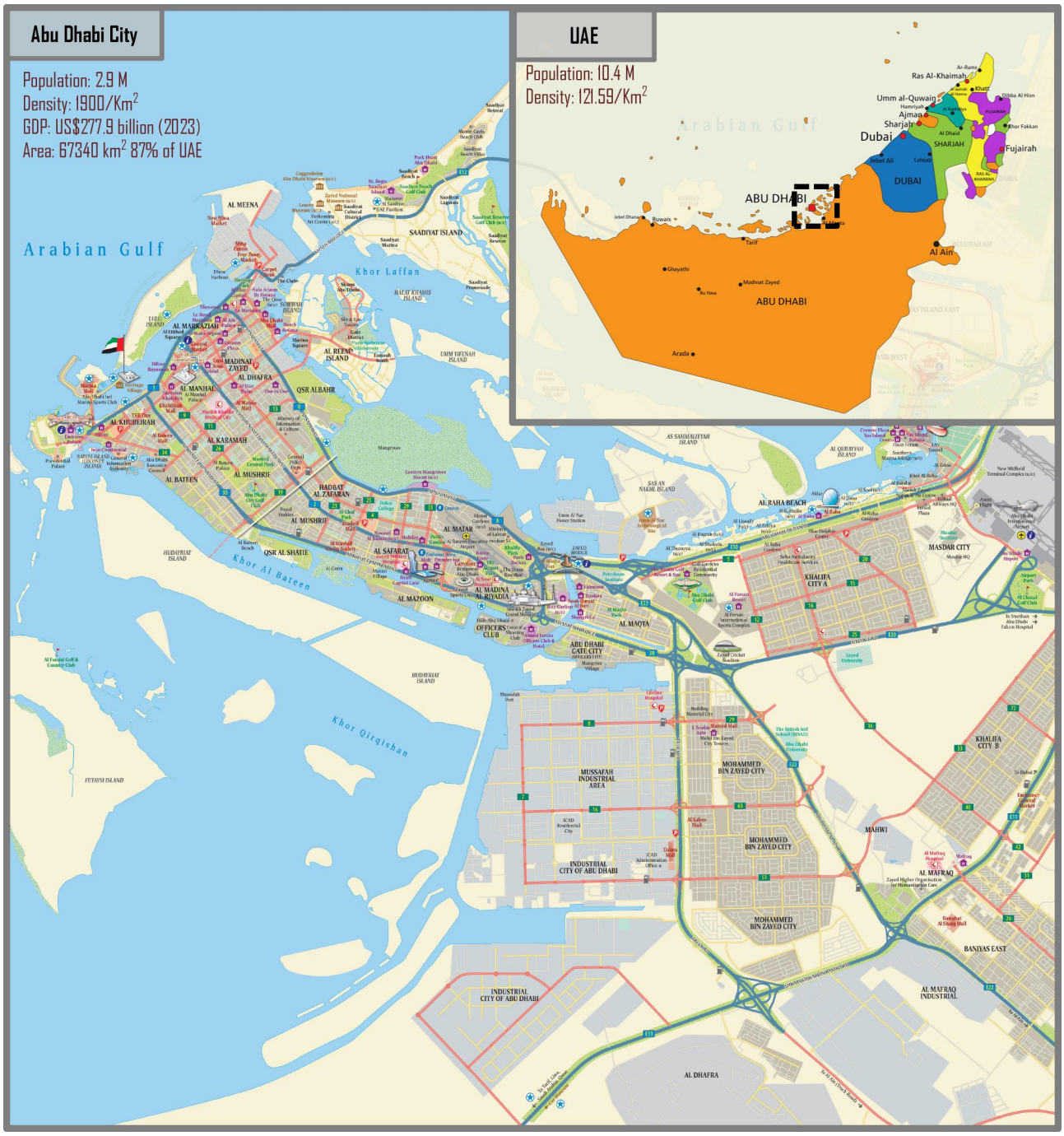


**FIGURE 1** UAE and Abu Dhabi maps [4, 5]. UAE, United Arab Emirates.

transportation links, mixed-use areas, and high-quality urban services [10]. An essential element of achieving this is creating more effective public transportation catering to the economy's needs. Advancements in technology have allowed the invention of innovative methods for urban services, which are employed to create sustainable smart cities (SSCs). These SSCs prioritise providing sustainable and efficient solutions for energy management, transportation, healthcare, governance, and other areas to meet the demands of urbanisation and sustainability. Despite a lack of consensus on SSCs, the concept has become increasingly prevalent in planning documents and national policies worldwide. Nevertheless, some urban policy authorities are apprehensive about implementing policies that would make their cities 'smart' [11].

Cities face new physical and digitalisation-related problems, including resource depletion, poor air quality, waste management, traffic congestion, and inadequate infrastructure [12]. Cities have faced various difficulties in recent years, such as social exclusion, high pollution levels, poor climate mitigation, stagnant urban productivity, and inadequate urban governance that overlooks the promotion of the SSC concept. Additionally, there is a need to improve the understanding of strategic planning for SSC initiatives in the literature. More attention should be given to studying the SSC objectives, including its theoretical development and assessment of the challenges that prevent its implementation in a country [13]. Consequently, it is critical to recognise and evaluate the major barriers to the growth of SSC.

This study aims to expand the current understanding of how to implement SSC by investigating the barriers that hinder the adoption of SSC principles in Abu Dhabi. SSC concepts may be successfully applied by identifying and prioritising intervention techniques according to the relevance of each barrier. Specifically, this research sets the following objectives: (i) to identify, rank, and prioritise relevant barriers to SSC development in Abu Dhabi and (ii) to model the interaction between the identified barriers to SSC development in Abu Dhabi. The barriers were selected using both literature and professionals' opinions. The results of this study will serve as a blueprint for an advanced SSC in Abu Dhabi.

## 2 | LITERATURE REVIEW

### 2.1 | Sustainable smart cities

It has been recognised that SSC can be achieved by utilising advancements in Information and Communication Technology (ICT). However, while progress has been made, the development of frameworks for essential elements and standards has yet to mature fully. Scholars are still seeking a widely accepted solution [14].

There are various ways to define SSC; the term is only sometimes used consistently. It's possible to replace 'smart' with other adjectives like 'intelligent' or 'digital'. There is no one definition or single approach for building an SSC. However, several definitions depend on how the term is used [15]. According to a study conducted by Albino [15], approximately 20 different definitions of SSC exist. The researchers suggested that SSC is a complex concept, as it encompasses two distinct domains: hard domains (such as buildings, energy, mobility, and logistics) where ICT plays a significant role, and soft domains such as education, social integration, and innovative regulations.

Various authors have defined the term SSC differently [16]. However, integrating and using ICT in different aspects of municipal services to enhance efficient and effective urban administration is universally recognised as the concept of SSC. The idea of SSC has evolved, and standardisation organisations now provide generally accepted explanations. To develop SSC, specific fundamental components and procedures have been identified.

### 2.2 | The rationale for SSC in Abu Dhabi

SSC use ICT to boost efficiency, educate residents, provide better public services, and enhance citizen welfare. The ultimate goal of applying technology in SSC is to optimise municipal operations, stimulate economic growth, and facilitate the inhabitants' quality of life. As we expect around 2.5 billion individuals to relocate to urban areas by 2050, it becomes crucial to sustainably manage resources to ensure environmental, social, and economic sustainability. SSC enables citizens and local authorities to manage resources and assets effectively in an ever-growing urban environment [17].

Studies have shown that implementing SSC can greatly improve urban areas' competitiveness, sustainability, and overall quality of life. Berrone and Ricart [18] produced the cities in motion index (CIMI), which evaluates 77 variables across 10 critical aspects of urban living, such as human capital, environment, transportation, urban design, public administration, and governance. Based on CIMI data, Abu Dhabi ranks 116th out of 183 cities globally in 2024.

According to the Smart City Index, Abu Dhabi has earned the prestigious title of one of the smartest cities in the region for two consecutive years in 2023. The 'International Institute for Management Development' and the 'Singapore University of Technology and Design' collaborated to produce the third annual 'IMD-SUTD SC index (SCI)'. The report highlights the significant influence of the digital revolution, which has been further accelerated by the pandemic, on urban residents' perceptions of how technology can positively impact urban concerns [19]. The report ranks Abu Dhabi as the 13th most intelligent city out of 118, while Dubai ranks 17th in 2023 [20]. Whereas, before the last index to be discussed is the global cities index introduced by the company AT Kearney. It is one of the oldest existing smart city indexes introduced, starting from 2008. It ranks Abu Dhabi as the 66th while Dubai is the 23rd of 156 cities. Last, according to the SECI by SmartEcoCity Ltd. Abu Dhabi is ranked 15th among 100 cities in Asia.

## 2.3 | SSC's initiatives, policies, and legal framework in Abu Dhabi

The UAE government has implemented measures and programmes to mitigate and adapt to climate change while balancing social and economic development fields [21]. The 'Green Economy Strategy for Sustainable Development' and the UAE's Vision 2021 exemplify the UAE's dedication to sustainable development. The 'National Environmental and Awareness Strategy 2015–2021' seeks to raise environmental consciousness among public, private, and local community partners. To inculcate in them a sense of responsibility for environmental conservation, it was created by the Ministry of the Environment in response to these national goals. A Strategic Plan for 2014–2016 was also released by the Ministry of Public Works, which emphasises sustainable infrastructure development and promotes the use of energy-efficient technology.

The 'Emirates Authority for Standardisation and Metrology' has also started enforcing strict energy-efficiency guidelines and labelling programmes for air conditioning systems, electrical appliances, lighting systems, and plumbing fixtures [22]. Other organisations in this regard include 'Bee'ah' and 'Tadweer' for waste management and 'Ras Al Khaimah Environmental Protection and Development Authority' for environmental protection. Sustainability-focused NGOs like the 'Environmental Centre for Arab Towns, Emirates Wildlife Society, Emirates Environment Group, and Emirates Green Building Council' are dedicated to sustainable strategies and regulations. The UAE's vision for 2021 seeks to boost processed waste to 75%, green technology to 24%, and the quality of air index to 90% [23].

The country's capital Abu Dhabi plans to have 16 GW of green generation capacity by 2035, roughly double the current level. The UAE is the first Gulf state to declare a target to reach net zero carbon emissions by 2050. Under the UAE's Net Zero by 2050 initiative, Abu Dhabi's upcoming renewable energy projects including the (5.6 GW) Barakah nuclear energy plant and the 2 GW Al Dhafra Solar PV project will produce a total clean power generation capacity of 8.8 GW by 2025. This initiative means 55% of Abu Dhabi's electricity in 2025 will come from clean sources and reduce power generation emissions from 40 million tons of $CO_2$ emissions in 2020 to about 20 million tons in 2025 [24]. Masdar City, a 600-ha development in Abu Dhabi, aims to provide residents with a complete living environment while conserving up to 60% of its waste production, 40% of its power, and 70% of its water. The city is anticipated to assist Abu Dhabi in achieving its 2050 objectives [25]. Since the Shams solar power plant opened in 2013, Masdar has been producing 100 MW of concentrated solar energy, increasing renewable energy output by 449% in 2014. The UAE government has seriously considered using underground and desalinated water because of its implications for the food and energy production fields [26].

The government has implemented several biodiversity policies, diversified its food supply, and invested in agricultural projects to address the problem of food security, given that more than 90% of its food is imported [27]. Adopting environmentally friendly waste management procedures and sustainable transportation strategies are additional goals for the UAE. For instance, the Estidama framework, developed in 2008 and addressing sustainability pillars, has been swiftly welcomed, adopted, and implemented in Abu Dhabi. The sustainable Pearl Rating System was awarded to over 13,500 structures in 2015. The governments of Abu Dhabi have made a determined effort to promote sustainability by enacting several resolutions [23].

# 3 | RESEARCH METHODOLOGY

## 3.1 | Extraction of barriers to SSC

The barriers to implementing SSC, particularly in Abu Dhabi, were identified from the literature. The literature has been explored using specific keywords, including 'barriers and smart cities development'; 'challenges and smart cities development', and 'problems/issues and smart cities development', utilising the databases of 'Scopus' and 'Google Scholar'. A detailed examination of keywords in numerous literature studies led to discovering the 31 primary barriers to the evolution of SSC. Additionally, we looked at specific government reports, legislative documents, online materials, and urban plans to determine the barriers to establishing SSC. A thorough literature review revealed 31 barriers related to 6 different categories of SSC development. The Abu Dhabi case scenario was used to perform this investigation (case study). The case study methodology is important for the theoretical advancement of the field (advocacy for SSC). The research methodology is shown in Figure 2.

Sixteen Abu Dhabi industry experts with at least 5 years of work experience participated in semi-structured interviewing. Semi-structured interviewing serves two purposes: (i) to validate the barriers discovered from the literature and (ii) to discover prospective barriers that still need to be identified. The experts agreed that each barrier applies to the circumstances in Abu Dhabi, and no additional barriers are proposed.


**FIGURE 2** Research flow.

## 3.2 | Respondents' demographic information

After conducting interviews, a survey was administered, which included a questionnaire. The first section of the questionnaire collected demographic information from the respondents. The second section used a 5-point Likert scale to gauge the significance of barriers. This survey was targeted at professionals from industries in Abu Dhabi. To validate the questionnaire's content, 16 experts were interviewed regarding the barriers to implementing SSC. The experts were selected based on their qualifications and work experience, requiring at least 5 years of experience and up to 20 years [28]. This is because the concept of smart cities has been in effect for at most 20 years, and in the Middle East, it has only been around for the last 10–15 years. The construction of the first smart city development project in the Middle East, Masdar City in Abu Dhabi, began in 2008 and was expected to be completed by 2030 [29]. Table 1 provides a demographic overview of the 140 experts who met specific criteria, helping to clarify their demographic backgrounds.

According to Luthra et al. [30], the specialists must have broad and comprehensive knowledge of the topic. The experts are highly qualified and have extensive experience in operations and finance, project management, and decision-making.

## 3.3 | Reliability and validity assessment

Kaiser-Meyer-Olkin (KMO) adequateness of the sample measurement was carried out to evaluate the factor's homogeneity and establish whether the partial correlations between the variables are minimal [31]. According to Tabachnick et al. [32], a factor analysis must have a minimum KMO value of 0.6 to be successful. KMO for this study is 0.819, which is higher than the required minimum. Bartlett's assessment of sphericity produced a significant outcome, indicating that factor analysis is suitable for the data ($\chi^2$ (465) = 2413.378, $p < 0.00$).

## 3.4 | Exploratory factor analysis

The research includes the results of an 'exploratory factor analysis (EFA)' to ensure the reliability of the questionnaire [33]. According to Tabachnick et al. [32], 100–300 samples are sufficient to conduct an EFA in this situation. Two hundred and fifteen questionnaires were distributed for this study, of which 140 valid replies were received. This sample size is adequate for analysis [33].

**TABLE 1** Demographic data of experts.

| Category | Classification | No. of experts |
|---|---|---|
| Educational qualification | Bachelor | 92 |
| | Master | 27 |
| | Ph.D. | 21 |
| Work experience | 5–10 years | 24% |
| | 11–15 years | 44% |
| | 16–20 years | 32% |

## 3.5 | Partial least squares structural equation modelling

In this study, we employed structural equation modelling (SEM) as our method of choice. This powerful tool is widely used in social science research to assess how well a proposed model aligns with the observed data and to identify potential cause-and-effect relationships. Specifically, we utilised partial least squares structural equation modelling (PLS-SEM) to verify further the results obtained from our initial EFA. While the EFA helped us uncover our data's underlying factor structure, the PLS-SEM provided us with a confirmatory factor analysis. This approach allowed us to optimise the explained variance between the latent variables. The PLS-SEM analysis was conducted in two stages. During the first stage, we analysed the outer loading of latent variables, discriminatory validity, and composite reliability (CR). We measured the relationship between latent and dependent variables in the second stage by estimating the beta (path coefficient) [34].

# 4 | RESULTS

## 4.1 | Barriers to SSC development

Identifying the crucial obstacles can assist both national and city governments develop SSC. Therefore, this section outlines the key barriers to the growth of SSC, which can serve as a useful reference for experts in the future. These barriers are categorised into six main areas in Table 2, including government-related, social interaction, technological, environmental, legal, and economic barriers.

The issue at hand is why certain barriers exist, and how we can overcome them. Policymakers should implement appropriate policies that help to reduce or eliminate such barriers. These policies may include measures to increase the adoption of electric vehicles, improve transportation networks, reduce $CO_2$ emissions, encourage the development of green buildings, conserve energy, promote the use of clean energy sources, monitor energy usage through smart metres, provide affordable energy, improve digital networks, and expand green spaces, among other things [28]. Table 2 displays the six main categories that have been the focus of many studies on barriers to the development of SSCs. The table also shows the references that are relevant to each category. Each category was evaluated separately to identify the barriers, which are summarised in Table 3. In total, 31 critical barriers were identified that are hindering the development of SSCs. While relevant studies have highlighted the importance of these barriers, there is a gap in research on these barriers in the UAE, specifically in its capital city, Abu Dhabi. Hence, this study aims to examine the barriers facing the development of SSCs in Abu Dhabi.

**TABLE 2** Main categories of barriers.

| Category | Description | References |
|---|---|---|
| Governance (GOV) | Smart governance is by using technology and innovation to improve governing bodies decision-making. A governance ecosystem can assist the government in strategically building long-lasting ties with citizens. Shared goal and a good reputation for the city, a functional metropolitan region, effectively operating electronic government, and a data-open city | [35] |
| Social (SOC) | The quality of life, smart services, social fairness, and citizen engagement are all examples of social sustainability. Administrative hierarchy, cultural context, demographic structure, and government administration and services are examples of social factors. ICT is used by SSC to enhance the services they offer and the welfare of their residents | [36] |
| Technology (TECH) | The infrastructure of SSC is based on digital networks. Enhancing environmental and sustainability objectives using linked technologies. In order to manage city facilities, SSC employ technology. Diverse technologies used to collect and analysing data to support decision-making and thus enhance services and facilities in the city | [37] |
| Environment (ENV) | Smart management systems for waste, energy, and water consumption are all parts of a smart environment. Smart environment enhances urban environmental quality. Neighbourhoods at SSC are made for strolling, and bike lanes are included in the design. Automobiles decrease with effective public transit, walkable neighbourhoods, and ride-sharing programmes | [37] |
| Economy (ECO) | Technological advancement, efficiency of resources, and sustainable practices are the cornerstones of a prosperous smart economy. Innovation and creative problem-solving attract new businesses, create jobs, and generate additional revenue streams—boosting economic development for cities | [36] |
| Legal and ethical (L&E) | Open urban government, transparency, and accountability are practiced in ethical cities along with the eradication of corruption, conflicts of interest, and power abuse. To prevent deteriorating over time and becoming less appealing, sustainable, and more susceptible to shocks and megatrends, cities should establish ethical futures, social inclusiveness, and citizen involvement | [38] |

**TABLE 3** The categories breakdown and linked barriers to SSC evolution.

| Category | No. | Barrier | Explanation | References |
|---|---|---|---|---|
| GOV | 1 | 'Lack of cooperation and coordination between the City's operational networks (GOV1)' | Insufficient connections between active nodes during the evolution of SSC | [35] |
| | 2 | 'Unclear it management vision (GOV2)' | The inability to see how IT administration may be used to the advancement of SSC | [38] |
| | 3 | 'Political instability (GOV3)' | SSC will not take off unless there is stability in politics | [35] |
| | 4 | 'Lack of trust between governed and government (GOV4)' | The growth of SSC might be hampered by a lack of public trust in the administration | [39] |
| | 5 | 'Poor private-public participation (GOV5)' | Projects to construct SSC may be poorly impacted by poor private-public cooperation | [14] |
| | 6 | 'Lack of developing a common information system model (GOV6)' | The absence of a unified IS model for managing the services and infrastructure of SSC to offer end-to-end visibility | [35] |
| ECO | 7 | 'High IT infrastructure and intelligence deficit (ECO1)' | Insufficient IT infrastructure (e.g. data centres, solar-powered systems) and AI capabilities | [39] |
| | 8 | 'Lack of competitiveness (ECO2)' | Local businesses' 'lack of competitiveness' in addressing the difficulties encountered in the establishment of SSC | [39] |
| | 9 | 'Cost of it training and skills development (ECO3)' | The growth of the SC is hampered by the expensive 'cost of it training and skills development' programmes for IT experts | [38] |
| | 10 | 'Global economy volatility (ECO4)' | Growing economic instability and uncertainty might pose a serious threat to the growth of SSC | [38] |
| | 11 | 'Higher operational and maintenance cost (ECO5)' | Concerns related to the high costs of operation and maintenance, which include expenses for the technology used and its personnel, consulting services and training | [38] |
| SOC | 12 | 'Lack of involvement of citizens (SOC1)' | The absence of input from individuals in understanding precisely how SSC may appear in their experience is evident. The public has to be urged to propose and assess innovative solutions for SSC design | [35] |

(Continues)

**TABLE 3** (Continued)

| Category | No. | Barrier | Explanation | References |
|---|---|---|---|---|
| | 13 | 'Low awareness level of community (SOC2)' | The public is unaware of the concept of a SC and how it may affect their life's quality | [35] |
| | 14 | 'Geographical diversification problems (SOC3)' | Geographical imbalance might impede the growth of the SC | [39] |
| | 15 | 'Degree of inequality (SOC4)' | The growth of the SSC might be hampered by a high 'degree of inequality' in the people's education, economic benefits, skills, and other factors | [39] |
| TECH | 16 | 'Lacking technological knowledge among the planners (TECH1)' | In the development of SSC planners and policymakers lack the enabling or revolutionary technology expertise that may be required | [35] |
| | 17 | 'Lack of access to technology (TECH2)' | The development of SSC may be hampered by the majority of inhabitants' limited access to contemporary digital technologies | [39] |
| | 18 | 'Privacy and security issues (TECH3)' | The establishment of SSC is frequently plagued by 'privacy and security issues', especially from hackers and malware that trespass the privacy | [38] |
| | 19 | 'System failures issues (TECH4)' | Numerous variables, including hardware failures, software faults, power outages, network problems, human error, or a combination of these things, are to blame for this failure | [35] |
| | 20 | 'Integration and convergence issues across it networks (TECH5)' | The evolution of SSC may be hampered by a lack of technological connectivity and the exchange of heterogeneous networks like 'bluetooth, WLAN and cellular networks like 3G, 4G, and 5G' among others | [35] |
| | 21 | 'Poor data availability and scalability (TECH6)' | The development plan for SSC is lacking in precise data and appropriate scalable solutions | [16] |
| ENV | 22 | 'Lacking ecological view in behaviour (ENV1)' | Absence of environmental perspective in environmentally sustainable energy usage | [35] |
| | 23 | 'Growing population problems (ENV2)' | Concerns with the growth of the SC may arise from the rapidly growing population | [16] |
| | 24 | 'Lack of sustainability considerations (ENV3)' | Higher living experiences for all are impossible without a more sustainable and aware city (one that can control traffic, inform inhabitants about available parking, emissions reduction etc.) | [16] |
| | 25 | 'Carbon emissions effect (ENV4)' | Cities' failure to transform into zero carbon initiatives and emission reduction measures | [38] |
| | 26 | 'Degradation of resources (ENV5)' | Shortage of resources, including a lack of drinking water and food | [39] |
| L&E | 27 | 'Cultural issues (L&E1)' | The dearth of creativity and communal living cultures among residents | [39] |
| | 28 | 'Lacking standardisation (L&E2)' | The lack of consistency among measurements (such as advanced technologies, security, confidentiality, standard of life, sustainable development, physical facilities, wireless networks etc.) is one of the fundamental issues in the concept of SSC | [35] |
| | 29 | 'Issues of openness of data (L&E3)' | In SSC, data openness and its availability are a problem that may make it more difficult to provide citizens and companies with the services they need | [35] |
| | 30 | 'Lack of transparency and liability (L&E4)' | The delivery of most services may be constrained by a lack of transparency and ambiguous political accountability, which might be problematic for the development of SSC. The absence of openness runs the risk of alienating the people that SC technology is meant to help | [38] |
| | 31 | 'Lack of regulatory norms, policies and directions (L&E5)' | Inadequate regulation and guidelines | [38] |

Abbreviation: SSC, sustainable smart city.

Creating an SSC requires extensive planning and careful implementation due to the inheritance of technical, management, and governance issues. However, solutions for digital states are still in their early stages.

## 4.2 | EFA of the barriers

The study used EFA to assess the relationship between different factors. EFA helps group many variables together, making them easier to understand and use. The anti-image correlation matrix's diagonals were all higher than 0.5, confirming that all items were included in the component analysis. Variables with low values (0.3) were not included in the factor analysis, and initial communalities are projections of each variable's variance constituents. In this study, all starting communalities were above the cutoff, and all loading factors were above 0.5, as shown in Table 4. Table 4 shows the mean scores and standard deviations of the barriers. All barriers with mean values below 2 were to be removed. However, all barriers were kept because they had mean values >2.

According to the EFA analysis, six factors were identified with eigenvalues >1. These factors were named legal & ethical (L&E), environmental (ENV), technology (TECH), social (SOC), economic (ECO), and governance (GOV). The L&E factor was found to be the most significant factor, explaining 62.627% of the variation. The second most significant factor was ENV, accounting for 58.181% of the variation, followed by TECH at 52.762%, SOC at 45.889%, ECO at 38.776%, and GOV at 26.513%. These results were obtained after applying the Varimax rotation method, as presented in Table 5.

After conducting the EFA, Cronbach's alpha test was used to evaluate the reliability and internal consistency of the barriers. Table 6 shows that Cronbach's alpha coefficients were acceptable, with values >0.7, ranging from 0.745 to 0.897. However, some items were removed from the EFA analysis due to their low weightings on all factors and low communalities. These items include GOV6, TECH1, and L&E5.

**TABLE 4** The communalities of barriers with their ranking according to the mean and SD.

| Code | Communalities | Mean | Ranking based on mean | SD | Ranking based on SD |
|---|---|---|---|---|---|
| GOV1 | 0.524 | 3.91 | 2 | 0.647 | 30 |
| GOV2 | 0.609 | 3.91 | 3 | 0.658 | 29 |
| GOV3 | 0.564 | 3.74 | 7 | 0.440 | 31 |
| GOV4 | 0.752 | 3.48 | 15 | 0.793 | 26 |
| GOV5 | 0.767 | 3.49 | 14 | 0.784 | 27 |
| GOV6 | 0.692 | 3.36 | 22 | 0.851 | 19 |
| ECO1 | 0.716 | 3.09 | 29 | 0.908 | 11 |
| ECO2 | 0.691 | 3.16 | 27 | 0.870 | 12 |
| ECO3 | 0.543 | 3.33 | 23 | 0.863 | 14 |
| ECO4 | 0.787 | 3.37 | 20 | 0.835 | 23 |
| ECO5 | 0.763 | 3.37 | 21 | 0.854 | 17 |
| SOC1 | 0.660 | 3.45 | 16 | 0.764 | 28 |
| SOC2 | 0.728 | 2.96 | 30 | 0.842 | 21 |
| SOC3 | 0.546 | 2.95 | 31 | 0.837 | 22 |
| SOC4 | 0.792 | 3.14 | 28 | 0.864 | 13 |
| TECH1 | 0.585 | 3.41 | 18 | 0.824 | 24 |
| TECH2 | 0.651 | 3.42 | 17 | 0.807 | 25 |
| TECH3 | 0.573 | 3.40 | 19 | 0.848 | 20 |
| TECH4 | 0.682 | 3.30 | 25 | 0.857 | 16 |
| TECH5 | 0.768 | 3.29 | 26 | 0.853 | 18 |
| TECH6 | 0.679 | 3.33 | 24 | 0.863 | 15 |
| ENV1 | 0.673 | 3.78 | 4 | 1.240 | 1 |
| ENV2 | 0.833 | 3.64 | 13 | 1.029 | 8 |
| ENV3 | 0.852 | 3.65 | 11 | 1.075 | 6 |
| ENV4 | 0.770 | 3.73 | 8 | 1.128 | 2 |
| ENV5 | 0.581 | 4.13 | 1 | 1.096 | 4 |
| LE1 | 0.707 | 3.72 | 9 | 1.029 | 7 |
| LE2 | 0.722 | 3.75 | 6 | 0.993 | 9 |
| LE3 | 0.835 | 3.76 | 5 | 1.089 | 5 |
| LE4 | 0.847 | 3.72 | 10 | 1.097 | 3 |
| LE5 | 0.685 | 3.65 | 12 | 0.908 | 10 |

### 4.2.1 | Governance

GOV is the primary barrier to establishing SSC. It includes the six barriers. The success of implementing SSC programmes relies on overcoming these interconnected barriers. One of the primary barriers to the establishment of SSC is governance. This category would influence all categories. SSC's implementation must consider several factors, including the (nation, government etc.). Governance is one of the key challenges in building an efficient SSC network. To properly manage various city programmes, there is a greater need for a stronger governance [38]. The item with the most importance in this category is (GOV4).

Establishing trust between the government and the people is important for successfully implementing smart city (SSC) initiatives. Various scholars have emphasised the significance of trust in this context. Engaging citizens in addressing data privacy and security concerns related to SSC is essential to build trust [40]. Encouraging private-public partnerships and investments is crucial for effective governance and implementation of SSC initiatives (GOV5). Strategic planning requires stable political leadership to envision the future clearly (GOV3). Integrating digital technologies with development initiatives is vital to the success of SSC, according to Chourab et al. [38] (GOV2). Collaboration and coordination among local governments and the city's operating network are critical

**TABLE 5** Barriers factor loadings.

| | Component | | | | | |
|---|---|---|---|---|---|---|
| **Barrier** | **1** | **2** | **3** | **4** | **5** | **6** |
| ECO1 | 0.714 | | | | | |
| ECO5 | 0.709 | | | | | |
| ECO2 | 0.628 | | | | | |
| ECO3 | 0.615 | | | | | |
| ECO4 | 0.807 | | | | | |
| TECH5 | | 0.810 | | | | |
| TECH4 | | 0.692 | | | | |
| TECH3 | | 0.590 | | | | |
| TECH6 | | 0.577 | | | | |
| TECH2 | | 0.527 | | | | |
| GOV2 | | | 0.749 | | | |
| GOV4 | | | 0.702 | | | |
| GOV5 | | | 0.682 | | | |
| GOV1 | | | 0.643 | | | |
| GOV3 | | | 0.437 | | | |
| LE4 | | | | 0.907 | | |
| LE3 | | | | 0.905 | | |
| LE2 | | | | 0.820 | | |
| LE1 | | | | 0.817 | | |
| SOC4 | | | | | 0.847 | |
| SOC2 | | | | | 0.772 | |
| SOC3 | | | | | 0.512 | |
| SOC1 | | | | | 0.654 | |
| ENV3 | | | | | | 0.899 |
| ENV2 | | | | | | 0.873 |
| ENV4 | | | | | | 0.849 |
| ENV1 | | | | | | 0.782 |
| ENV5 | | | | | | 0.723 |

*Note*: 'Extraction method: principal component analysis'. 'Rotation method: Varimax with Kaiser normalisation'.

**TABLE 6** Reliability assessment.

| **Category** | **Reliability** |
|---|---|
| GOV | 0.897 |
| ECO | 0.778 |
| SOC | 0.765 |
| TECH | 0.852 |
| ENV | 0.745 |
| L&E | 0.789 |

for effective SSC implementation (GOV1). Finally, (GOV6) was eliminated due to its low importance and lack of relevance to the other items.

### 4.2.2 | Economics

Among all of the barrier categories, the economics category is crucial. To analyse data and information, SSC requires extensive infrastructure and digital technologies built on enormous networks of sensors, monitors, recording devices, smart appliances, electricity grids etc. Governmental limits and funding allocation are important determinants in infrastructure development, according to Guy et al. [41]. The ECO category includes five barriers, among which ECO5 prioritises. Technologists and operators must concentrate on increasing the system's effectiveness to enhance its sustainability [42]. The next barrier is ECO4. The state of the world economy can affect the availability of subsidies, resulting in higher or lower greenhouse gas emissions. Therefore, ECO1 illustrates the necessity for broad infrastructure and smart technologies to establish SSC, which can be expensive. ECO2 is the next barrier that focuses on controlling urban areas to increase economic viability, offer social security, and maintain the environment that urban areas need to be controlled to increase economic viability, offer social security, and maintain the environment [39], which the government does not always do. The last barrier is ECO3, which requires more sophisticated IT training and expertise and can be expensive.

### 4.2.3 | Social

The next priority on the list of barriers is the social category, which brings up various societal concerns, such as safety, education, and the environment. Addressing these challenges is crucial in the establishment of SSC. According to experts, significant socioeconomic issues arise due to demographic shifts, and negative environmental impacts may result if appropriate measures are not taken. The social category comprises four key barriers, with SOC2 being the primary one. Community involvement is crucial in planning and executing SSC projects, making SOC4 the next significant barrier. To establish SSC successfully, addressing citizen disparity is vital. The third barrier, SOC3, is the vast geographic diversity in Abu Dhabi that requires comprehensive data to evaluate urban issues and geographical processes. Finally, SOC1 is the last barrier on the hierarchy, where citizens' lack of interest and involvement hinders progress. Encouraging residents to participate in decision-making is crucial for SSC officials.

### 4.2.4 | Technology

For the development of SSC, technology innovations have emerged as a widely recognised trend and are expected to

play a crucial role in terms of providing connectivity and intelligence in SSC. Several technological innovations in SSC are related to IoT [43], Autonomous Vehicles [44], Smart Energy Technology [45], Big Data [46], Artificial Intelligence [47], Blockchain Technology [48], Smart Wearable Devices [49], and Cloud IoT [50]. Technology innovations will be crucial to advancing the city's efficiency and the citizens' quality of life [51]. The first barrier in this category is (TECH6). SSC development lacks accurate data and appropriate scalable solutions, as governments should work on providing solutions related to data quality and adaptability. Big data processing will help facilitate real-time forecasts, manage data movement, accountability, enhance decision and policy making, handle emergencies etc. [52]. The network of the SSC is particularly vulnerable to various cyber-attacks in addition to other incidents, including industrial espionage, terrorist attacks, equipment failures, worm infestations, and natural hazards which represent the next barrier in this category (TECH4). By maintaining the SSC networks from the above-mentioned hazards, it will successfully overcome the barrier of security and privacy problems and create safe cities (TECH3) [40]. SSC necessitates technological know-how among city citizens (TECH2). The citizens in cities should have wide access to technology. Governments would provide educational initiatives to show the city citizens how to use the necessary technology and make it accessible effectively [53]. The growing number of intelligent devices in SSC has resulted in several connection barriers that may hinder the advancement of current communication technologies (TECH5). In order to facilitate communication between disparate networks and technologies, interoperability concerns must be addressed. Barriers pertaining to architecture, allocating resources, accessibility management, quality of service, and privacy arise when disparate technologies are integrated to efficiently offer value-added applications and services [54]. The last barrier in this category (TECH1) was excluded from the EFA due to its low weightings on all factors.

### 4.2.5 | Environmental

The fifth significant type of barrier is ENV. Therefore, authorities, stakeholders, and people must focus on assessing various ecological factors, such as pollution, climate change, soil, and minerals. It is also necessary to encourage people to reduce their water and energy consumption to minimise carbon emissions [55]. The environmental category consists of five barriers. The top rating is (ENV2). The population living in Abu Dhabi city is likely to increase due to the increasing urbanisation in the country. There will be higher demands on resources as the population increases. The next barrier is the (ENV3). For ecological advantages, policy-makers should consider sustainability while building resilient SSC structures. The following barrier is (ENV4). According to Ajaj et al. [56], they are increasing urbanisation results in higher carbon emissions and less sustainability. The following barrier is (ENV1). It suggests that a thorough approach must be employed to motivate people to consider actions from an ecological perspective. The last item on the list is (ENV5).

### 4.2.6 | Legal & ethical

SSC poses several cultural, ethical, and legal concerns. The (L&E4) shows that citizens' participation and enhanced integrity in governance are essential for successfully establishing SSC. The following barrier in this category is (L&E3) which concerns the openness of data. Rathore et al. [57] noted the importance of data openness in their analysis of the SSC initiatives. The openness and integrity of data shall benefit all populations (L&E2) is the following barrier. Standardisation and regulatory guidelines for successfully administering and applying IoT-based networks are lacking. The following are (L&E1) to SSC establishment. The last barrier is (L&E5). To maintain the system's accessibility and keep track of all the parties involved, well-specified governing standards, regulations, and directives are required. It was excluded from the EFA due to its low weightings on all factors and had low commonalities.

## 5 | STRUCTURAL MODEL OF THE BARRIERS

The structural model illustrating the links between the constructs is determined, which also evaluates the correlations between items and latent variables [58]. The evaluation of the measuring model is shown in Table 7. The CR must be above 0.7, and the Cronbach's alpha must be above 0.5. Additionally, the loadings of the factors of the confirmatory factor analysis and average variance extracted (AVE) must be above 0.5 [58].

Table 8 presents the Cross Loadings for each model item. Three items, (ENV1) and (ENV5) pertaining to the Environmental category, and (SCO1) from the social category, which had factor loadings below 0.5, were eliminated from the model since they had minor or no impact on the category. To demonstrate that there is no link between the categories, the discriminant validity was assessed using Fornell Larckers and Cross Loading [58]. The square root of AVE's must be higher than the correlation between latent variables. The results shown in Table 8 validate the discriminant validity of the model. According to Table 8 results, and as shown in Figure 3, all loading values for the assigned latent constructs are higher than cross-loading for other constructs.

Six subscales can be used to illustrate the barriers as illustrated in Table 9. The route coefficients show that all of these factors are major barriers to establishing an SSC in Abu Dhabi.

**TABLE 7** Result of convergent validity.

| | Cronbach's alpha | CR | AVE |
|---|---|---|---|
| Barriers to SSC | 0.883 | 0.895 | 0.265 |
| ECO | 0.841 | 0.888 | 0.613 |
| ENV | 0.73 | 0.8 | 0.504 |
| GOV | 0.805 | 0.865 | 0.569 |
| L&E | 0.901 | 0.93 | 0.77 |
| SOC | 0.757 | 0.765 | 0.463 |
| TECH | 0.86 | 0.9 | 0.643 |

**TABLE 8** Cross loading.

| Barrier | ECO | ENV | GOV | L&E | SOC | TECH |
|---|---|---|---|---|---|---|
| ECO1 | 0.763 | | | | | |
| ECO2 | 0.748 | | | | | |
| ECO3 | 0.743 | | | | | |
| ECO4 | 0.815 | | | | | |
| ECO5 | 0.84 | | | | | |
| ENV1 | | 0.234 | | | | |
| ENV2 | | 0.954 | | | | |
| ENV3 | | 0.905 | | | | |
| ENV4 | | 0.828 | | | | |
| ENV5 | | 0.225 | | | | |
| GOV1 | | | 0.578 | | | |
| GOV2 | | | 0.656 | | | |
| GOV3 | | | 0.718 | | | |
| GOV4 | | | 0.887 | | | |
| GOV5 | | | 0.882 | | | |
| L&E1 | | | | 0.835 | | |
| L&E2 | | | | 0.865 | | |
| L&E3 | | | | 0.903 | | |
| L&E4 | | | | 0.905 | | |
| SOC1 | | | | | 0.387 | |
| SOC2 | | | | | 0.766 | |
| SOC3 | | | | | 0.742 | |
| SOC4 | | | | | 0.75 | |
| TECH2 | | | | | | 0.82 |
| TECH3 | | | | | | 0.713 |
| TECH4 | | | | | | 0.825 |
| TECH5 | | | | | | 0.81 |
| TECH6 | | | | | | 0.835 |

## 6 | DISCUSSIONS AND CONTRIBUTIONS

This research is important for Abu Dhabi's decision-makers as it helps them understand the obstacles to implementing SSC successfully. The success of SSC depends heavily on its administration, which can be improved through better governance. This will enable greater collaboration between all parties involved in the development of SSC, enhancing the impact of public participation and policy choices related to it. To increase accountability and transparency in decision-making, government administrators and citizens may advocate for e-governance services. This will aid in creating smart governance for SSC. Managing resources, including people and equipment, is crucial when developing SSC. While obtaining funds and building the necessary infrastructure for SSC projects continues to be a challenge, governments need to have a solid plan that involves both public and private sector engagement. Sufficient resources and funds must be allocated to SSC projects. This study could be useful in addressing resource and infrastructure-related problems. Furthermore, automation and digitalisation are essential to create a truly SSC in the future. Innovative digital technologies can assist in managing infrastructure, improving service levels, fostering collaboration, and outlining government initiatives to address climate change-related challenges.

In addition, to compare the research contribution with previous research, researchers such as Veselitskaya et al. [59] explain in their analysis of the main aspects and barriers to the development of SSC that each city uses a variety of tools that have caused different progress. For example, the more sophisticated smart city approach of Barcelona (creation of a special office responsible for the smart city, high citizen participation in planning, etc.) has helped it become one of the best SSCs in the world. The urban planning systems in Shanghai, Tokyo, and Charlotte are not very flexible. This is why these cities apply only separate approaches to developing smart cities. Rana et al. [28] also studied barriers in Indian cities and found that cities in developing countries differ greatly in the design and implementation of SSC. Moreover, different experts may have different opinions regarding the barriers to the development of SSC. SSC implementation is highly context-dependent (countries, governments etc.). The main barriers in the aforementioned cities are Barcelona (land lease and conflict of interest of municipal authorities, citizens, and business), Charlotte (intellectual property protection, confidentiality of personal information, and security of automated systems), Shanghai (land lease, lack of opportunities for citizens to participate in city management, lack of resources, the plan is the main document that determines the city development), Tokyo (security of automated systems, lack of opportunities for citizen to participate in city management, the plan is the main document that determines the city development), and India context (lack of involvement of citizens, lack of competitiveness, and global economy volatility).

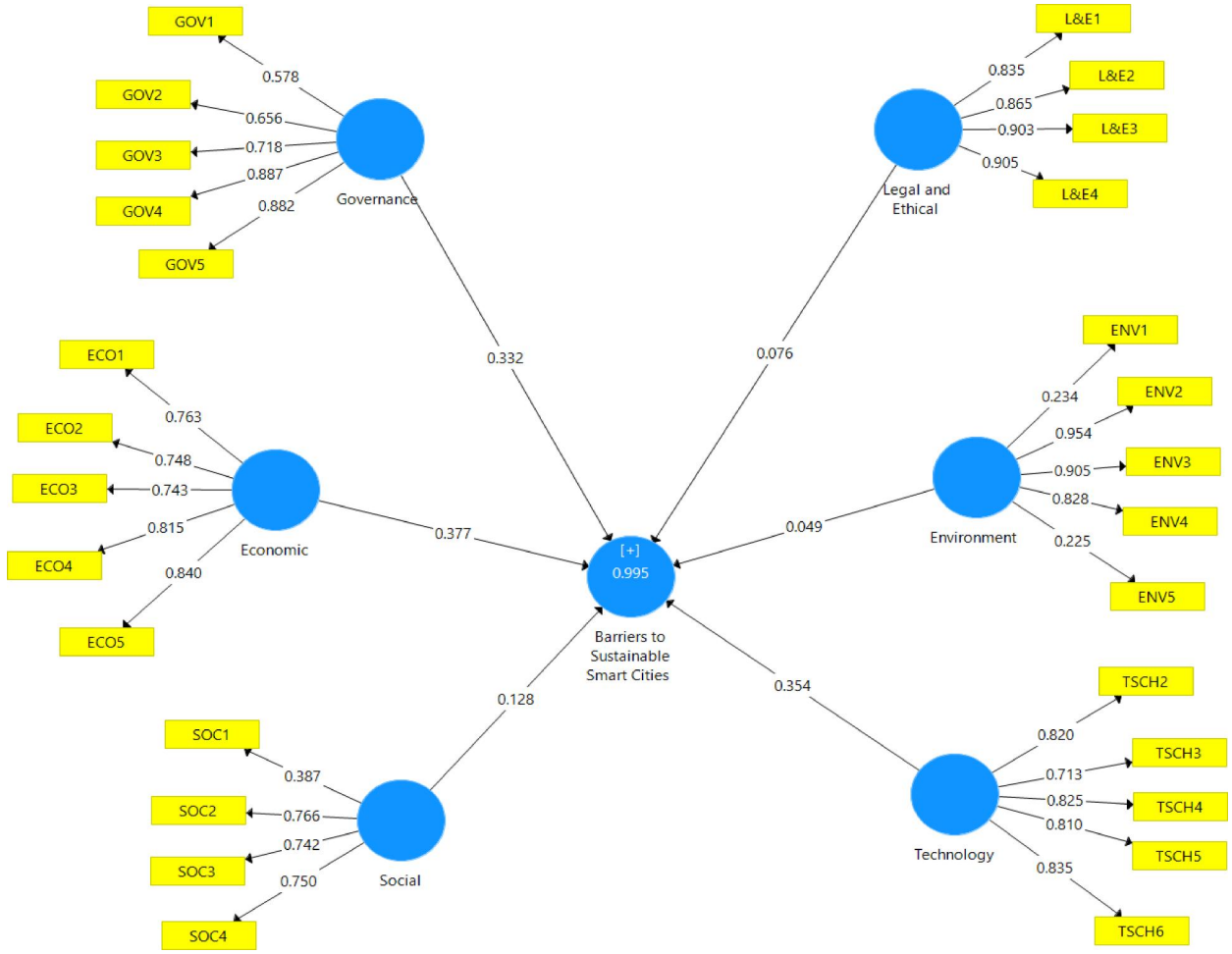


**FIGURE 3** Structural model.

**TABLE 9** Test of second-order models.

| Constructs | Outer loading | *T* values | *p* value |
|---|---|---|---|
| Gov | 0.332 | 12.436 | 0 |
| ECO | 0.377 | 13.539 | 0 |
| SOC | 0.128 | 5.807 | 0 |
| TECH | 0.354 | 13.821 | 0 |
| ENV | 0.049 | 1.349 | 0.028 |
| L&E | 0.076 | 1.719 | 0.036 |

## 6.1 | Results comparison with other cities

Urban SSC project implementation encounters various challenges, which vary in nature, ranging from general financial difficulties to particular limitations contingent upon each city's socioeconomic, environmental, and political features [60]. Despite being actively implemented in several developed cities around the world, SSC projects have limited applicability in cities within the Gulf Cooperation Council (GCC) [61]. Transitioning towards the SSC model in GCC cities poses various challenges that are socio-economic, political, technical, and infrastructural in nature. The effectiveness of such a transition depends on how well these components are integrated. Experts in Abu Dhabi have identified and prioritised the barriers, and these results must be compared with other related studies from different cities worldwide. This comparison, presented in Table 10, serves to demonstrate the original contribution of this research and confirms that the barriers are affected by the unique socio-economic, environmental, and political characteristics of each city.

Developing and transitioning towards SSC poses several challenges. Some challenges are unique to a specific city or country within a region, while others are common to all cities worldwide. Despite these challenges, the region has been embracing the SSC trend for the past 5 years and has made a remarkable progress in implementing SSC initiatives. However, there is still a great deal of variation in the implementation of these efforts within the regions and countries. While some cities have made significant strides in adopting SSC, others have yet to begin transitioning towards sustainable development, a crucial factor to consider when implementing SSC. The evidence suggests that the rate at which the shift towards SSC occurs varies widely, both across nations in the region and within cities in a single country.

**TABLE 10** Comparison of the barriers across various cities.

| City | Barriers (not limited to) | References |
|---|---|---|
| Abu dhabi | • Growing issues with the population | This research results |
| | • Concerns about data transparency | |
| | • Lack of accountability and transparency | |
| | • Failure to take sustainability into account | |
| | • Lack of confidence between the governed and the government | |
| Saudi Arabia | • A lack of knowledge or interest in smart services | [62] |
| | • Limited selection of languages | |
| | • People's lack of desire to switch to using smart services | |
| | • Inadequate facilities | |
| Qatar | • Low levels of social capital and innovative potential | [63] |
| | • Slow adoption rates in rural communities | |
| | • Limited local market capacity | |
| | • Geographical remoteness and underdeveloped networks for transportation and communication | |
| | • Excessive workload, inadequate rewards, low recognition, weak management support, insufficient experience, inadequate training, and resistance to change | |
| Iraq | • The security deterioration | [64] |
| | • Increased population growth along with the severe shortage of housing | |
| | • Lack of environmental awareness among the government and the citizens | |
| | • Lack of utilisation of primary resources due to the heavy reliance on external imports | |
| | • The absence of an integrated planning system | |
| Pakistan | • Financial restraint | [65] |
| | • Insufficient resources | |
| | • Absence of solutions with a sustainable focus | |
| | • Residents' lack of knowledge about smart cities | |
| India | • Citizens' lack of participation | [66] |
| | • Insufficient competitiveness | |
| | • Volatility of the world economy | |
| | • Unrest in politics | |
| Shanghai | • Land contract | [59] |
| | • Citizens' lack of participation options in city management | |
| | • Insufficient resources | |
| Tokyo | • Automated system security | [59] |
| | • Citizens' lack of participation options in city management | |
| | • The primary document that guides municipal growth is the plan | |
| Charlotte | • Protection of intellectual property | [59] |
| | • Protection of personal data confidentiality | |
| | • Automated system security | |
| Barcelona | • Potential for conflicts to arise between the interests of governmental leaders, private capital, and the general public | [59] |
| | • The city has a 'from top to bottom' development plan | |
| | • Land leases are the result of urban dynamics and austerity policies | |

**TABLE 10** (Continued)

| City | Barriers (not limited to) | References |
|---|---|---|
| Prague | • Bureaucracy | [67] |
| | • Long tenders | |
| | • Tight financing | |
| | • Threat to intellectual property | |
| Bolzano | • Fragmented property ownership | [60] |
| | • Perception of actions as costly, intricate, and having detrimental effects on the environment or society | |
| | • Restricted capital availability and financial disincentives | |

How SSC programmes are implemented differs among cities. According to study analysis, Tunisia started e-administration development in the 1990s to modernise its administrative system. More recently, efforts have focused on e-services generalisation and setting up the necessary frameworks so that e-government organisations may achieve their goals. In December 2006, Bahrain declared its intention to become the premier e-government player in the Gulf by releasing new e-government plans. This would be accomplished, among many other things, by offering more services online via various channels, such as portals, cell phones, contact centres, and post offices. Jordan is also putting its e-government plan into practice, with three primary axes of emphasis: the service framework, the infrastructural framework, and the legal framework. Egypt concentrated on enhancing the range of internet services and expanding the channels through which they are delivered. Many initiatives have been started, especially those involving database creation. In Oman, the goal of the 'Oman' ICT strategy was to 'transform the Sultanate of Oman into a sustainable knowledge-based society by leveraging ICT to enhance e-government services, enrich businesses, and empower individuals' and was approved in 2003. The 'eOman' strategy emphasised integrating many levels, including developing capacity, shared central architectural components, e-government initiatives, and legal and regulatory frameworks controlling electronic transactions. E-government was listed as a national goal by the State of Palestine in all of its primary policy documents and plans. ICT has gradually become more significant, with differing depth and relevance. It is completely incorporated in all Palestinian attempts to create a contemporary, effective, well-run government administration. In closing, Iraq used ICT tools to improve basic services to everyone and to promote overall good governance, including increased public participation, better social equity, and justice, as well as a general enhancement of transparency and effectiveness of public institutions to lay the groundwork for a competitive, robust, and information-based economy. This was done by implementing the e-governance action plan [68].

It is necessary to contrast the UAE Smart Dubai version with the smart cities in the West. The political and economic distinctions of the city from those in the West are marked by its authoritarian administration system, a reaction against the informality of old Dubai, and widespread employment of foreign workers, who have extremely limited residency rights across all industries and economic levels. Furthermore, Dubai's top priority is the development of a smart city infrastructure that is intended to maintain the depoliticisation of its citizens, gather information from them, and maintain social, cultural, political, and economic supremacy over them in tandem with Smart Dubai's intensification of the city's formalism. This is demonstrated by Dubai's emphasis on using its infrastructure to carry out the systematised and ubiquitous surveillance and tracking of its citizens—Emirati and expatriates alike—as they move through the city [69].

There are differences in the efforts put into putting SSC initiatives into action. Given the close connection between the development of SSC and e-government services, the rate at which national SSC strategies and action plans are implemented impacts the evolution towards SSC. Table 11 shows the SSC initiatives and types in the region to highlight the importance of this research aim by identifying the barriers.

SSC in the UAE is on a path that sets it apart from its equivalents in the globe and that has to be understood in the context of the region in which it operates. It is important to recognise the importance of the city's concentrated smart city initiative as well as its authoritarian government system. The greatest indicator of the city's distinction from smart city projects in the globe is perhaps how quickly SSC has been implemented and how much it has infiltrated citizens' daily lives. These factors also speak to the effectiveness of the city's governance structure and the lack of significant opposition to any aspect of the project. The pastoral aspects of a smart city, such as communications, efficiency, entertainment, and sustainability, are represented by Smart UAE, which is a model for smart cities in the global south and east, including Beijing and Singapore, which are building smart infrastructures very similarly to Dubai's.

## 7 | CONCLUSION

Over the past two decades, building SSC has gained a lot of deep discussion in scholarly research worldwide. We identify and prioritise barriers to the development of SSC to assist

**TABLE 11** Sustainable smart city status in the region [70].

| Country | Type of initiatives |
|---|---|
| Algeria | Brownfield, greenfield |
| Bahrain | Brownfield |
| Djibouti | Greenfield |
| Egypt | Greenfield |
| Jordan | Brownfield |
| Kuwait | Brownfield, greenfield |
| Lebanon | Greenfield |
| Morocco | Brownfield, greenfield |
| Oman | Brownfield |
| State of Palestine | Brownfield/greenfield |
| Qatar | Brownfield/greenfield |
| Tunisia | Greenfield |
| Saudi Arabia | Brownfield/greenfield |
| United Arab Emirates | Brownfield/greenfield |

decision-makers in enhancing UAE's sustainability, particularly Abu Dhabi city. To prioritise the chosen barriers in this work, SEM using the PLS route modelling approach was used. Thirty-one barriers to the establishment of SSC were identified after an in-depth analysis of literature. The experts support the selection of these barriers. With the help of industry professionals, we divided these barriers into 6 categories. The results revealed the significance of all categories for SSC development; the categories are 'Governance', 'Economic', 'Technology', 'Social', 'Environmental' and 'Legal and Ethical'. According to the ranking of barriers (ENV2), (ENV3), (L&E4), (L&E3) and (GOV4) have been identified as the top 5 barriers to the establishment of SSC in Abu Dhabi. The identified barriers will help produce action plans and address the barriers effectively in Abu Dhabi.

Identifying barriers to SSC is sorely needed in the Abu Dhabi industries so that appropriate and practical interventions can be proposed and employed by the government, organisations, and policymakers to take the barriers down and improve SSC performance progressively. The practical interventions include establishing an appropriate system of governance at the national level to support the implementation of SSC concepts so that SSC can gradually become an integral part of all industries' activities. In this form of government, the establishment of SSC guidelines and its effective enforcement are crucial. This will force industries to consider SSC elements while conducting their operations. SSC awareness and commitment may be built at the organisational level by ongoing commitment to SSC at the national and industrial levels. To assure advancement and alter the Abu Dhabi industries, it is essential to maintain consistency in this coordinated endeavour to build SSC.

### 7.1 | Research limits and future opportunities

This research does have some limitations. The results were heavily influenced by expert judgements. Implementing SSC is highly context-dependent (nations, governments, etc.). The research is specific to the city of Abu Dhabi, as it has various unique characteristics that depend on its size, technology, population density, culture, government practices and systems, societal diversity, economy, oil-based energy sources, initiatives, policies, and legal framework. Due to these specific characteristics, Abu Dhabi is distinct from other cities, and it may only be appropriate to apply this study to another city after first analysing the possibility of applying the research results. It would be valuable to conduct further analysis on the extracted barriers to better understand their causal relationships in the development of SSC. Future research could also explore the critical success factors that impact the growth of SSC and how they are connected to the identified barriers. This could aid researchers in determining the priorities of different countries and cities based on sustainability standards, while also considering the limitations that may hinder adoption in those areas. Ultimately, this information could help decision-makers take effective action and complement the results of this study. The researchers might also use the interpretive structural modelling technique to better comprehend the dependent and driving barriers. One of the most crucial elements in SSC is the people. To avoid stakeholder resistance and the failure of SSC, it is also necessary to analyse how people and government personnel see various elements of SSC using proven theories and models.

## AUTHOR CONTRIBUTIONS

**Rahaf Ajaj**: Conceptualisation; funding acquisition; methodology; resources; investigation; project administration; supervision; writing – original draft; writing – review & editing. **Mohanad Kamil Buniya**: Data curation; formal analysis; methodology; validation; visualisation. **Ibrahim Yahaya Wuni**: Conceptualisation; project administration; resources; software; validation. **Omar Sedeeq Yousif**: Conceptualisation; data curation; formal analysis; investigation; methodology; resources; software; validation; visualisation; writing – original draft; writing – review & editing.

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## CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to disclose.

## DATA AVAILABILITY STATEMENT

The data supporting this study's results are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy or ethical restrictions.

## ORCID

*Rahaf Ajaj* https://orcid.org/0000-0003-3539-2879
*Mohanad Kamil Buniya* https://orcid.org/0000-0002-7360-6148
*Ibrahim Yahaya Wuni* https://orcid.org/0000-0002-0070-8637
*Omar Sedeeq Yousif* https://orcid.org/0000-0002-2965-2972

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