Journal of Urban Management 14 (2025) 843–855

Contents lists available at ScienceDirect

Journal of Urban Management

journal homepage: www.elsevier.com/locate/jum

Research Article

A structural equation model of the critical success factors for sustainable smart cities: A case study of Abu Dhabi

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ARTICLE INFO

Keywords:
Abu Dhabi
Prioritisation
Smart city
Success factors
Sustainable development
Smart urbanism

ABSTRACT

Sustainable Smart Cities (SSCs) have garnered significant attention due to the accelerating rate of urbanization, and digitalization recently. The main objective of SSC initiatives is to seamlessly integrate digital technology into the city's fundamental systems, ultimately enhancing the citizens' quality of life. In light of this, a study was conducted to pinpoint the Critical Success Factors (CSFs) necessary for Abu Dhabi's transformation into SSC. These CSFs were identified via an investigation of the literature and further confirmed by practitioners via semi-structured interviews and questionnaires. Through these methods, the research demonstrated a robust correlation between SSC implementation and CSFs. With this in mind, the study identified 22 CSFs across four primary categories: people and communities, governance, technology, and management and organization. The study then prioritized these CSFs for Abu Dhabi, highlighting the importance of end-user involvement, accountability, good communication, and project team skills and experience in boosting the implementation of SSC initiatives. Ultimately, it is crucial to consider and prioritize CSFs when designing SSCs to ensure that they truly benefit citizens and the economy. This research provides a useful framework for cities around the world looking to create and implement SSC initiatives that will enhance their citizens' quality of life.

1. Introduction

Cities worldwide are quickly becoming man-made ecosystems made of sentient digital creatures that are interdependent and networked (Bello et al., 2024). Most people on the planet now reside in cities, and there are an increasing number of high-density cities being built. The notion of Sustainable Smart City (SSC) is, nonetheless, a relatively recent one that is transforming people's communities, transportation, employment opportunities, and way of life (De Marco & Mangano, 2021/01).

In the past, people primarily resided in rural areas due to urban sprawl. However, recently, there has been a significant change, and many individuals have moved to cities. According to the United Nations World Urbanization Outlook, over half of the global populace

This article is part of a special issue entitled: Advancing Urban and Territorial Performance published in Journal of Urban Management.

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https://doi.org/10.1016/j.jum.2025.02.008
Received 14 June 2024; Received in revised form 2 October 2024; Accepted 25 February 2025
Available online 6 March 2025

(55%) lived in cities in 2017, with 4.1 billion populace residing in urban setting (Liu et al., 2021). Based on United Nations study in 2018, by 2050, 68% of people on Earth are projected to live in cities, which is twice the number of people in rural areas (DESA, 2018).

As more people move into metropolitan areas, managing infrastructure and public transportation becomes increasingly challenging while also maintaining a sustainable economy. It is worth noting that cities account for only two percent of the global land area but are responsible for 80% of carbon emissions and 75% of energy consumption (Satterthwaite, 2008). The growing demands of cities and their inhabitants are forcing governments to adopt a smarter approach to making better use of available and future resources (Fan & Chapman, 2024). Cities are not only the primary energy consumers but also the driving force behind the global economy, contributing to 50% of the globe's GDP (in urban setting with populations of more than 750,000) and contributing $10–15 trillion to the global GDP output. To ensure sustainable development, governments must implement models based on renewable energy and technologies that alter the industry's structure and the attitudes of key stakeholders. As urban areas continue to grow, cities and their residents will face new challenges as key players in this transformation (Ajaj et al., 2019).

In today's world, social media and telecommunications have a significant impact on how people form their social and cultural personalities. This can have an impact on an individual's decision to relocate. The SSC is gaining popularity as it offers a unique perspective on sustainable development, standard of living and innovative use of technology. To successfully implement the Sustainable Development and SSC concepts, governments must adapt to the changing needs of their citizens (Antwi-Afari et al., 2021/01).

In order to establish SSC, service providers need to exercise significant economic and commercial ingenuity due to the high degree of innovation required (Bibri, 2021). However, governments have struggled to transform traditional cities into SSCs mainly because of the challenges in implementing SSC principles. The scarcity of resources like freshwater or food supply, insufficient connections between active nodes during the evolution of SSC, and concerns with the growth of the SSC due to the rapidly increasing population are some of the significant challenges. Another challenge is the issue of data openness (Almuraqab, 2021). To improve the success rate of transforming traditional cities into SSCs, it is essential to understand and prioritize the "Critical Success Factors (CSFs)" for implementing SSCs in practice. Thus, this research aims to contribute to the discourse and investigate the CSFs for transforming traditional cities like Abu Dhabi into SSCs. This research goals include reviewing the scientific literature and extracting relevant CSFs, assessing, and prioritizing CSFs under the framework of Abu Dhabi, and investigating the interconnections between the CSFs through structural equation modeling. Fig. 1 shown the UAE map highlighting Abu Dhabi. CSFs help governments focus their attention and resources on areas crucial for achieving favorable results quickly and effectively.

2. Research background

2.1. Sustainable smart cities SSCs

In recent urban development research, the concept of SSCs has gained prominence. SSCs are designed to promote social and environmental sustainability (Vanolo, 2014; Zygiaris, 2013). Various definitions exist for SSCs. The urban planning community employs the term SSC to refer to a concept that entails the need for strategic direction to become smarter (Albino et al., 2015). Efforts to enhance environmentally friendly, societal, logistical, and rivalry aspects of business infrastructures have resulted in the development of SSC. SSC is comprised of infrastructure, themes, and elements that collectively enable their development. The elements of a SSCs are often referred to as SSC characteristics, while the themes are considered the pillars of its ongoing progress. Infrastructure, as the operational foundation, is a crucial component of any SSC (Kourtit & Nijkamp, 2012; Schaffers et al., 2011; Silva et al., 2018).

2.2. Smart city planning and implementation

Studies on several international experiments have concluded a number of initial steps that must be carried out in the existing cities to be transformed into smart cities. It begins by assessing the current city infrastructure and needs. When setting a smart city initiative, planners need to build a strong case, and that all starts with understanding the costs and the benefits. Planners have to consider city's priorities, both now and in the future. That will guide the development of smart city plan. Developing a smart city plan or roadmap requires a holistic approach balancing technology, community needs, governance, and financial sustainability. Developing a roadmap may seem like a complex undertaking, but selecting an experienced partner can help success the plan. Selecting the right smart city partner and plan can make the transition smooth and cost-effective. Fig. 2 shows an initial step of implementation, a simple framework for smart city transformation.

The planning begins by thoroughly assessing the city's current infrastructure, challenges, and future growth projections. Identify specific areas where smart technology can have a significant positive impact, such as transportation, energy, healthcare, public safety, or environmental sustainability. Then, clearly define objectives. Ensure that these objectives align with city's overarching vision and mission. Engage key stakeholders, including residents, local businesses, government departments, technology experts, and community organizations. Seek input from diverse perspectives and backgrounds to ensure the roadmap addresses various population segments' unique needs and concerns. Research and evaluate available smart technologies that align with the identified objectives. Consider the latest innovations in the field, their compatibility with existing systems, and their scalability to accommodate future growth. Evaluate potential technology partners and vendors for their expertise and reliability in delivering solutions. Develop comprehensive policies and strategies for data collection, storage, utilization, and sharing. Address data privacy and security concerns, ensuring all activities comply with relevant local, state, and federal regulations, industry standards, and best practices. Create a detailed budget outlining the costs of implementing smart technology solutions. This should encompass hardware, software, labor, and any associated infrastructure changes. Explore various funding sources, such as government grants, public-private partnerships, energy savings contracts, and other financing

Fig. 1. UAE map (GEOATLAS, 2024).

options to support the initiatives.

Prioritize projects based on their potential impact, feasibility, and alignment with the objectives. Plan for a phased approach to implementation, starting with smaller-scale pilot projects to test and validate technologies before moving on to full-scale deployment. Establish a system for ongoing adaptation and feedback collection, ensuring the roadmap remains flexible and responsive to changing circumstances, emerging technologies, and lessons learned from pilot projects. Continuously engage with the community to address feedback and concerns, informing residents about progress and outcomes. Develop a long-term maintenance plan to ensure the sustainability and innovation of smart technologies, keeping the city at the forefront of technological advancements.

2.3. SSCs initiatives in Abu Dhabi

Over the course of the last decade, the United Arab Emirates (UAE) main megalopolis, such as the cities of Abu Dhabi and Dubai, have undergone a significant transformation into SSCs. In keeping with the National Happiness policy in these cities, SSC activities are considered to be an integral component (Al-Azzawi, 2018). Nonetheless, due to their favorable international perception, Abu Dhabi and Dubai are well-positioned to attract foreign investment.

To elevate Abu Dhabi to the status of a leader in research and cooperation on clean technology, renewable energy and sustainable development, they establish the city of Masdar in 2006 to create the globe premier SSC (Griffiths & Sovacool, 2020). The goal was to provide economically feasible solutions for sustainable development and renewable energy while solving the sustainability issues facing

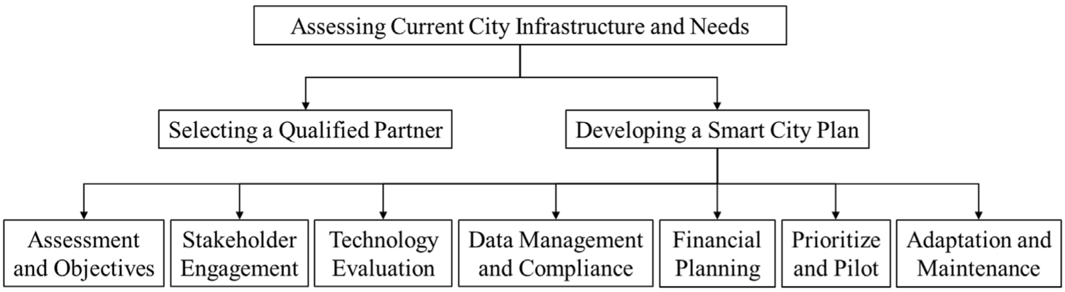

Fig. 2. SSC implementation roadmap.

the UAE. The “Masdar Institute of Science and Technology (MIST)”, is Abu Dhabi's primary financing initiative for research and education development, offering human and entrepreneurial resources for Masdar City's growth. MIST works together with the “Massachusetts Institute of Technology (MIT)” to promote advances in sustainable development. It amalgamated with “Khalifa University” in 2017. Abu Dhabi adheres to the UAE plan for cutting-edge innovation (2018) in terms of innovation policy, which aims to create an innovation platform. This policy inspired the creation of the “UAE Innovation Month” event. Abu Dhabi has announced a plan to build several large-scale free zones surrounding Masdar to attract creative businesses. Companies have been given prominent positions within Masdar City by Abu Dhabi (De Jong et al., 2019).

Mubadala Investment Company has started significant investments in the construction of information and communications technology infrastructure and systems and data assets. As Abu Dhabi's investment company, Mubadala is accountable for supplying funding and facilities via its own entities or by contracting out. In 2012, Mubadala established “Khazna Data Centers” to offer 18+ Megawatt IT load. The Abu Dhabi government's Mubadala Investment Company, which collaborates with the “International Renewable Energy Agency (IRENA)”, owns the majority of Masdar (Noori et al., 2020).

Abu Dhabi is more efficient than Dubai due to its abundant financial resources acquired from its oil and gas reserves. To expedite global sustainable development, Masdar City has organized Sustainability Week with a global perspective. This initiative brings together decision-makers from the public sector, business leaders, innovators in technology, and the younger generation of citizens to exchange ideas, implement plans, and provide solutions for the sustainable growth of the global community. As part of its research and development for Sustainable Smart Cities (SSC), Masdar has launched the Honeywell Masdar Innovation Center, which focuses on innovative solutions for smart applications (Noori et al., 2020).

Table 1
Main categories of CSFs.

#	Category	Code	Description	CSFs	Code	References
1	Management and organization	MO	Setting attainable objectives is crucial for the development of IT projects. Comprising end users and other pertinent stakeholders in the development process has shown to be a successful tactic for resolving MO issues.	“Project team skills and experience”	MO.1	Mahler and Regan (2003)
				“Technical and social skills”	MO.2	Joshi et al. (2016)
				“Clear goals”	MO.3	Garson (2003)
				“Identification and relevant stakeholders”	MO.4	Brown and Brudney (2003)
				“End-user involvement”	MO.5	Mahler and Regan (2003)
				“Planning”	MO.6	Melitski (2003)
				“Good communication”	MO.7	Dawes and Pardo (2002)
				“Adequate and innovative funding”	MO.8	Stephen H et al. (2003)
2	Technological	TECH	The utility and simplicity of use of an information system are two technology-related elements that can help them succeed. Owing to the relative novelty and complexity of some technologies, one way to address difficulties pertaining to information technology is to host talks on the technologies in order to raise awareness and concentrate initial efforts on creating system and process prototypes.	“IT training programs”	TECH.1	Ebrahim and Irani (2005)
				“IT management”	TECH.2	Chourabi et al. (2012)
				“Employees with integration skills and culture”	TECH.3	Barns (2018)
				“Cross–sectoral cooperation”	TECH.4	Burn and Robins (2003)
3	Governance	GOV	The application of creativity and technology to enable better planning and decision-making inside governing bodies.	“Collaboration”	GOV.1	Scholl et al. (2009)
				“Leadership and champion”	GOV.2	Lam (2005)
				“Participant and partnership”	GOV.3	Giffinger et al. (2007)
				“Communication”	GOV.4	Odendaal (2003)
				“Data exchange”	GOV.5	Nfuka and Rusu (2010)
				“Service and application integration”	GOV.6	Nfuka and Rusu (2010)
				“Accountability”	GOV.7	Johnston and Hansen (2015)
				“Transparency”	GOV.8	Johnston and Hansen (2015)
4	People and communities	PC	SSC is one that is ready to provide the circumstances necessary for a happy and healthy society despite the difficulties that may arise from social, political, economic, and environmental developments on a worldwide scale.	“Digital divide”	PC.1	Scholl et al. (2009)
				“Information and community “gatekeepers”	PC.2	Barzilai-Nahon (2009)
				“People participation”	PC.3	Giffinger et al. (2007)
				“Education”	PC.4	Odendaal (2003)
				“Quality of life”	PC.5	Rios (2012)
				“Accessibility”	PC.6	Partridge (2004)

The success of the SSC projects launched by the rulers of Dubai and Abu Dhabi is largely dependent on the leadership style, as it serves as a dynamic throughput in Emirati situations. The leader's vision is the foundation for inspiring and empowering the populace of UAE. On the other hand, in European contexts, two-way communication serves as the foundation for SSC.

2.4. Critical success factors for SSCs

CSFs are a few select fields that ensure effective competitiveness for governments, departments, or individuals. Governments use CSFs to concentrate on various aspects that guarantee project success and help define it. This helps the government, and its staff identify the most important areas to devote their time and resources. In the context of SSCs (Shared Service Centers), CSFs refer to the actions, materials, and conduct required for SSC initiatives to be implemented successfully (Alfaiz et al., 2021). This research has explored the literature from various disciplinary areas to identify these CSFs. Drawing from the results of earlier research into the execution of SSC initiatives, particularly in developing nations, these four categories—which are divided into the following 26 CSFs—have been taken into consideration as shown in Table 1.

Coordinating efforts among many stakeholders is necessary to develop SSCs to address the varied demands of residents in various areas. SSC development has been the subject of several studies. CSFs have been shown to make it clear which factors are more important for the development of SSCs. Fig. 3 shows the CSFs mind map of the 26 factors that were identified and classified in a simpler way to understand.

The PLS-SEM is the theoretical underpinning of the suggested model in this work, which aims to explain the factors influencing the government's continual desire to deploy SSCs. Thus, we hypothesized that the four categories would positively impact the adoption of SSCs. The research's suggested model is shown in Fig. 4. H1: MO have a beneficial role in the effective implementation of SSCs, H2: The effective deployment of SSCs is positively impacted by TECH, H3: GOV has a good impact on SSC implementation success, H4: PC have a positive impact on SSC implementation success.

3. Research methods

This research employed a combination of quantitative and qualitative methods, as the research procedure in Fig. 5 illustrates. Table 1 discusses a collection of CSFs identified from the literature. The factors for creating the questionnaire were reviewed and adjusted during a qualitative sixteen semi-structured interviews. Twenty-six CSFs were taken from the literature and confirmed by professionals to be assessed in the quantitative survey.

Using a list of SSC CSFs, industry professionals with the necessary industry expertise participated in a semi-structured interview (Ajaj et al., 2024). The factor structure of a measure was found and its internal reliability was assessed using the "Exploratory Factor Analysis (EFA)" approach based on the information obtained from the survey. The EFA results validated the CSFs' applicability. From the running of the EFA on the identified 26 CSFs the 4 categories have been fixed.

3.1. Respondents' demographic information

After conducting interviews, a survey was administered, which included a questionnaire. Respondents' demographic data was gathered in the 1st portion of the questionnaire. The relevance of CSFs was evaluated in the 2nd part using a five-point Likert scale. The professionals were asked to rank the importance of each CSF from 1 to 5. This survey targeted professionals from various industries in Abu Dhabi. To validate the questionnaire's content, 16 experts were interviewed regarding the CSFs to implement SSC in Abu Dhabi. The professionals were chosen in accordance with their qualifications and professional background, requiring at least five years of

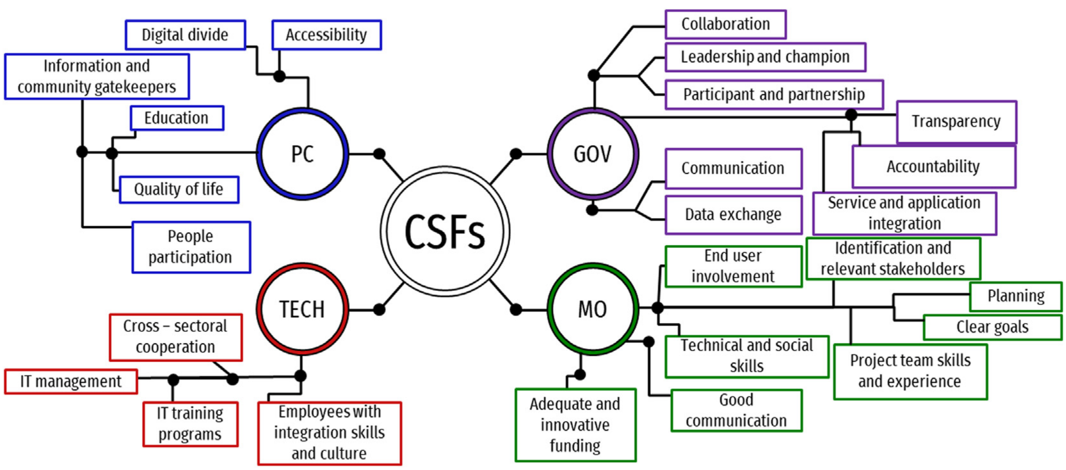

Fig. 3. CSFs mindmap.

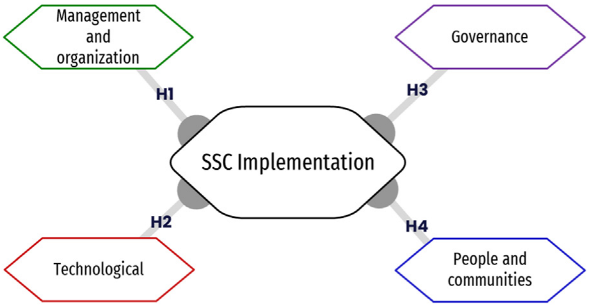

Fig. 4. The proposed model.

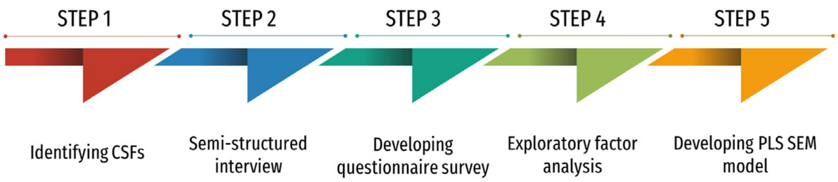

Fig. 5. Research flow.

experience and up to 20 years. This study focuses on CSFs identification and ranking, which highly depend on experienced, qualified personnel. This is because the concept of SSCs 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 (Dingle, 2023). Table 2 provides a demographic overview of the 140 experts who met specific criteria, helping to clarify their demographic backgrounds.

According to Luthra et al. (Luthra et al., 2016/09), 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. The data gathered from the questionnaire are rankings (1–5). It measures experts' attitudes to each CSF. To analyze the data, it has been coded MO.1, MO.2, etc.

3.2. Model development

Numerous academic fields have expressed interest in "Partial Least Square Structural Equation Modeling (PLS-SEM)" (Hair et al., 2017). PLS-SEM was employed to examine the data for its superior predictive capabilities to estimate the CSFs of the SSC efforts. PLS-SEM is a method for causal modeling using smaller, normal sample sets in order to maximize the dependent latent components' explained variance (Hair et al., 2017).

3.2.1. Measurement model

The connection between the items and their original latent structure is shown in this section. Convergent and discriminant validity of the measurement model were discussed in the sections that proceeded.

3.2.1.1. Convergent validity CV. The term CV refers to the level of agreement between two or more measurements (CSFs) of the same construct (group) (Hulland, 1999). It is thought to represent a subset of the validity of the construct. The CV of the measured constructs may be evaluated using the PLS model in three ways (Fornell & Larcker, 1981): "Cronbach's alpha (α)", "Composite Reliability (CR)", and "Average Variance Extracted (AVE)". A criterion of 0.7 for α and CR value was suggested (Nunnally & Bernstein, 1994) as the acceptable level of modest composite dependability (Fornell & Larcker, 1981). On the other hand, values more than 0.60 were suitable for exploratory research (Wong, 2013). AVE, on the other hand, was used as a normative measure to assess the CV of components in a model; values above 0.5 indicated a CV that was reasonable (Wong, 2013).

Table 2
Demographic data of responders.

Category	Grouping	Frequency
Educational qualification	Bachelor	92
	Master	27
	Ph.D.	21
Work experience	5 - 10/Years	24%
	11 - 15/Years	44%
	16 - 20/Years	32%

3.2.1.2. Discriminant validity DV. In addition to indicating that any measures not found in the phenomena are being tested in the SEM, the tested events are identified as empirically distinct by DV (Hair et al., 2010). According to Campbell and Fiske (Campbell & Fiske, 1959), discrimination cannot be proven if there are too many similarities across the measurements.

3.2.2. Structural model analysis

For the CSFs of SSC, this research generates a priority model using SEM. According to Hui and Zheng (Hui & Zheng, 2010), SEM is a helpful technique for handling variable errors. This approach may reduce a challenging decision-making procedure (Çakıt et al., 2020). The route coefficients RC between the observed coefficients must be provided in order to complete the analysis. The hypothesis of this study illustrates the direct relationship (route relationship) between μ (implementation CSFs) and α (concerns of SSC implementation components). The fundamental relationship in the linear equation is demonstrated by the structural connection between the α, μ, and $\bar{\alpha}1$ formula:

$$\mu = \beta\alpha + \bar{\alpha}1 \tag{1}$$

where $\bar{\alpha}1$ is the predicted residual variance at the structural level and (β) is the RC linking the CSFs of SSC implementation components. β is the uniform weight of the standardized regression, which is the same as the β weight of a multiple regression model. It indicates that the model projections are consistent and statistically meaningful.

Finding the RC significance is the next step. Using the bootstrapping method with PLS, the standard errors of the coefficients were determined using Confirmatory Factor Analysis (CFA). Five thousand subsamples, based for t-statistic proposition testing, were proposed by Henseler et al. (Henseler et al., 2016). Four structural equations were created for the SSC implementation CSF constructs in the PLS Model, describing the constructs' inner relationships and Equation (1).

4. Results

4.1. Suitability of data for EFA

"Kaiser-Meyer-Olkin (KMO)" adequateness of the sample measurement was conducted to evaluate the factor's homogeneity and determine if there are minimum partial correlations between the variables (Sharma, 1996). According to Tabachnick et al. (Tabachnick et al., 2007), a Factor Analysis FA must have at least a KMO of 0.6 to be successful. KMO for this study is 0.834, which is higher than the required minimum. Bartlett's assessment of sphericity produced a significant outcome, proving that FA is appropriate for the given data ($\chi2$ (325) = 2716.681, $p < 0.00$).

4.2. Categories of the CSFs for implementing SSC

The study used EFA to assess the relationship between different factors. EFA helps group many variables, making them easier to

Table 3
CSFs with their ranking according to the Mean and Std. Deviation (N = 140, Min = 1, Max = 5).

CSFs	Mean	SD	Ranking based on mean
MO.1	3.80	1.233	4
MO.2	3.62	1.036	15
MO.3	3.62	1.049	16
MO.4	3.69	1.108	8
MO.5	4.11	1.117	1
MO.6	3.72	1.226	7
MO.7	4.01	1.191	3
MO.8	3.62	1.341	12
TECH.1	3.68	0.993	10
TECH.2	3.69	0.964	9
TECH.3	3.73	1.083	6
TECH.4	3.63	1.086	11
GOV.1	3.60	0.896	17
GOV.2	3.62	0.995	13
GOV.3	3.44	0.987	25
GOV.4	3.37	1.028	26
GOV.5	3.56	1.073	20
GOV.6	3.50	0.996	22
GOV.7	4.11	0.994	2
GOV.8	3.52	0.902	21
PC.1	3.56	1.135	19
PC.2	3.62	1.184	14
PC.3	3.57	1.007	18
PC.4	3.48	0.989	24
PC.5	3.48	1.042	23
PC.6	3.77	1.060	5

understand and use. The "anti-image correlation matrix's" diagonals were above 0.5, confirming all items were included in the component analysis. Variables with low values (0.3) were not included in the FA, and initial communalities are projections of each variable's variance constituents. All starting commonalities were higher than the cutoff, and all "loading factors" were above 0.5. Table 3 shows the mean scores and standard deviations of the CSFs. All CSFs with mean values below 2 were to be removed. However, all CSFs were kept because they had mean values greater than 2.

From the 26 items that had analytical executions with eigenvalues larger than 1, four factors were taken out. As shown in Table 4, the four components provide a good explanation for the eigenvalues and total variance. However, some items were removed from the EFA analysis due to low Factor loading. These items include GOV.1, MO.1, MO.5, and MO.7.

4.3. CSFs of SSC implementation – SQM

4.3.1. Model of measurement

An active model is employed in the PLS algorithm analytic technique to determine the connection between the exogenous variable and its matching Latent Variable LV. CV, Discriminatory validity, and the Model's internal dependability are all evaluated at this point. CV comprises three tests: AVE, CR, and α. It indicates the degree of correlation that exists between two or more variables of the same group. The minimal AVE is 0.5, the lowest CR is 0.7, and the acceptable degree of dependability is 0.7 (Almakayeel et al., 2023). Table 5 demonstrates that every value satisfies the conditions.

Following the EFA, the α was used to assess the questionnaire's reliability (Yousif & Zakaria, 2022). The α values range from 0.7 to 0.873, as Table 6 demonstrates. Since every score is much higher than the cutoff point of 0.7, the components and the questionnaire are both deemed to be credible.

The Measurement Model cross-loadings for every model component are shown in Table 7. Cross-loading was used to evaluate the DV in order to show that there was no relationship between the categories (Hair et al., 2021). It is necessary for the square root of AVEs to exceed the association between LVs. The outcomes displayed in Table 7 support the model's DV. All loading values for the assigned latent constructs are larger than cross-loading for other constructs, as seen in Table 7 data and Fig. 6.

4.3.2. Second-order test

Formative LVs were CSFs' second order of importance. Using the bootstrap technique, the RC significance was assessed. The Variance Inflation Factor (VIF) value must be assessed to determine the formative components' collinearity. Since each VIF was less than 3.5, it was clear that each component made a separate contribution to the higher-order construct.

The resultant CSFs with 4 categories are displayed in Table 8: PC ($O = 0.327$, $p < 0.000$), GOV ($O = 0.624$, $p < 0.000$), MO ($O = 0.185$, $p < 0.002$), and TECH ($O = 0.117$, $p < 0.001$). The second-order findings demonstrated that the 4 categories had a major impact on SSC implementation. Path analysis is an approach for evaluating the connections between the components and investigating the study hypotheses. Table 8 demonstrates how the CSFs categories substantially and favorably impact SSC implementation.

Table 4
Factor loadings for 26 CSF items ($N = 140$).

Components	1	2	3	4
GOV.5	0.832			
GOV.2	0.825			
GOV.8	0.765			
GOV.6	0.762			
GOV.4	0.726			
GOV.3	0.712			
GOV.7	0.702			
PC.3		0.819		
PC.1		0.789		
PC.2		0.781		
PC.5		0.716		
PC.6		0.682		
PC.4		0.654		
MO.3			0.777	
MO.6			0.773	
MO.4			0.743	
MO.2			0.736	
MO.8			0.676	
TECH.3				0.512
TECH.4				0.496
TECH.1				0.470
TECH.2				0.511

"Extraction Method: Principal Component Analysis".
"Rotation Method: Varimax with Kaiser Normalization".

Table 5
Result of CV.

Category	α	CR	AVE
GOV	0.923	0.938	0.654
MO	0.825	0.864	0.646
PC	0.817	0.855	0.506
TECH	0.897	0.928	0.763

Table 6
Reliability assessment.

Category	GOV	MO	PC	TECH
GOV	0.809			
MO	0.243	0.7		
PC	0.79	0.253	0.711	
TECH	0.188	0.216	0.122	0.873

Table 7
Measurement model cross loading.

CSF	GOV	MO	PC	TECH
GOV.1	0.804			
GOV.2	0.825			
GOV.3	0.712			
GOV.4	0.726			
GOV.5	0.832			
GOV.6	0.762			
GOV.7	0.702			
GOV.8	0.765			
MO.2		0.738		
MO.3		0.699		
MO.4		0.729		
MO.5		0.625		
MO.6		0.714		
MO.7		0.595		
MO.8		0.677		
MO.1		0.536		
PC.1			0.854	
PC.2			0.812	
PC.3			0.841	
PC.4			0.6	
PC.5			0.531	
PC.6			0.548	
TECH.1				0.807
TECH.2				0.854
TECH.3				0.91
TECH.4				0.919

5. Discussion

This research's main goal was to create a structural model that combines the use of SSCs with CSFs. The purpose of this all-encompassing approach was to explore and comprehend the sufficient, suitable, and required circumstances (CSFs) for putting SSCs into practice. The research aimed to increase the use of SSCs and develop a better understanding of CSFs. The goal was to close the knowledge gap on the limited investigation of SSC success determinants to impact Abu Dhabi's transition to SSC. Specifically, the literature was examined, and relevant CSFs for implementing SSCs were extracted. Additionally, the extracted CSFs were assessed and ranked for the optimal successful implementation of SSCs. In conclusion, this research looked at the interlinkages among the CSFs for implementing SSCs using SEM.

The success of a SSC concept rely more on public engagement than on its technological advancements, such as ICT development or smart technology equipment (Granier & Kudo, 2016). Although accountable government and effective communication are also crucial factors that directly impact the performance of the SSC, they rank lower in significance than public engagement. Public participation is at the foundation of governance, and the citizen's viewpoint is essential as they are the ones who will live and work in the SSC (Tan and Taeihagh, 2020). All the Smart technology in the world would not matter much if the city's features and services do not align with the lifestyles that its residents desire.

SSC success cannot be ensured by ICT and infrastructure alone. While high-speed internet, wireless and Wi-Fi connectivity, cloud

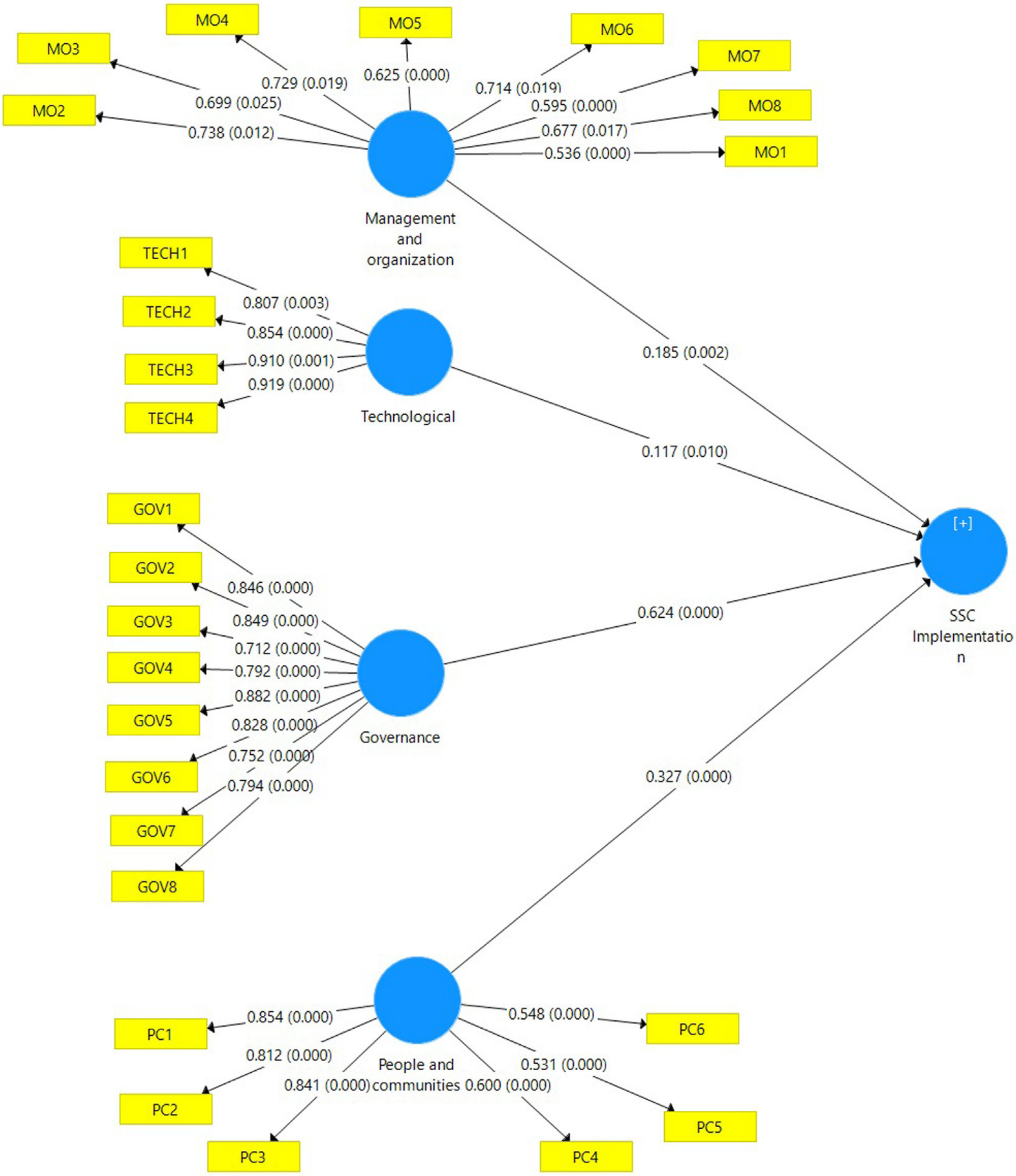

Fig. 6. Structural model.

Table 8
Second-order test.

Path	O	T	P
GOV → SSC implementation	0.624	14.75	0.000
MO → SSC implementation	0.185	3.098	0.002
PC → SSC implementation	0.327	11.069	0.000
TECH → SSC implementation	0.117	2.574	0.001

computing, and sensor networks are all crucial SSC enablers, they are just a part of the bigger picture. The Smartness of a city is equivalent to the satisfaction of its people (Flynn, 2022). In other words, the current state of ICT development is only an enabler, facilitating adaptable, intelligent services like emergency response systems, improved traffic management, and smart metering. ICT technologies help citizens participate more actively in the planning, developing, and providing services, empowering individuals to make more conscious and ecologically responsible decisions in their day-to-day lives. They also improve the transparency, responsiveness, accountability, and trustworthiness of local governments and administrations, fostering ongoing communication between businesses and the public (Penalosa Londono, 2024). Citizens and governments must work together to determine what it means to live in megacities, and ICT makes it possible to become a SSC by promoting citizen integration and the effective utilization of resources. A city must have the complete support of both its people and administration to become an SSC. They must acknowledge and address the significance of environmental, social, and economic issues. While ICT is necessary for overcoming these obstacles, it is not sufficient on its own.

The study's results highlight the significant impact of the abilities and experience of the project team on the implementation of SSCs. This emphasizes the importance of educating and training teams to build intelligent teams that can effectively shift towards SSCs, which offer exceptional services. Additionally, the study suggests that creating SSC applications with mediocre features and services may not be adequate. The likelihood of citizens using the SSC application increases only when they perceive it to provide high-quality services that meet their demands. These findings align with previous studies (Sta, 2017; Anttila & Jussila, 2018). This highlights the importance of service quality delivered by knowledgeable and experienced staff as a strong predictor of the SSC model that has a favorable impact on actual technology use. Furthermore, research conducted in the context of SSC (Kummitha & Crutzen, 2019/03; Chatterjee & Kar, 2018) has confirmed a positive correlation between citizens' cultural background and skill sets, and their intention to execute SSC projects. Moreover, the study revealed that this desire had a favorable impact on the implementation of SSC initiatives. Previous research also supports a positive correlation between the desire to execute and the actual execution of SSC efforts (Neupane et al., 2019–12; Abu Salim et al., 2021).

SSC technological applications allow systems to merge volumes of heterogeneous data from different sources to classify, analyze, and compare relevant information and its relationships to support decision-making (Tran Thi Hoang, Dupont, & Camargo, 2019). This integration allows for the classification, analysis, and comparison of relevant information, supporting decision-making in various fields. The integration of SSC technological systems is a critical aspect of ensuring that all stakeholders reap benefits. The primary objective of this integration lies in achieving interoperability, which facilitates cooperation between different businesses (Agbali, Trillo, Ibrahim, Arayici, & Fernando, 2019). Interoperability is the primary goal of SSC system integration since it enables cooperation across distinct and varied businesses. Information and knowledge are shared across enterprises through business processes and data transfers between the corresponding ICT systems (Ismail & Zhang, 2018). Puron-Cid and Gil-Garcia, (2022) suggests that understanding financial long-term sustainability might help us better comprehend smart city initiatives over the long run from a financial standpoint. To enhance the short- and long-term assessments of smart city projects, however, some other financial analytical tools and frameworks, like a cost-benefit analysis, return on investment, public value assessment, and stakeholder analysis, may also prove helpful in the endeavor to create a more integrative viewpoint.

5.1. Research implications

The study employs structural equation modeling to investigate the interconnections between the CSFs, aiming for transforming the current Abu Dhabi into SSC. The expansion of this research is particularly significant, as it anticipates the growing adoption of SSC in the field, which can optimize transformation procedures. Moreover, the study identifies key variables that effectively promote the execution of SSC initiatives in practice, offering valuable insights into the attitudes of governments and their future plans for SSC projects. The study also proposes strategies for enhancing the understanding of CSFs that should be considered when implementing SSCs. The research highlights the importance of maximizing technology resources within SSC to address technical challenges and underscores the relevance of aligning SSC projects with the needs and preferences of the public. Ultimately, this study emphasizes the vital role of governments in promoting the use of SSC technologies as a primary means of enhancing citizens' quality of life.

5.2. Research limitations and recommendations

While this research provides valuable information, yet there are certain limitations that can guide future research. Firstly, to ensure more comprehensive and dependable research outcomes on addressing the CSFs of SSC, the model presented in this study may benefit from additional components. Secondly, the study was confined to the Abu Dhabi metropolis in the UAE, making it necessary to replicate this research in other geographic locations to establish the generalizability of the findings. The CSFs are sensitive to context and most of the existing literature have called for a context-specific studies to make them more practical. And this informed the decision to study Abu Dhabi. Cross-cultural comparisons may also shed light on the cultural aspects associated with the SSC CSFs. Lastly, the study only considers the perspectives of professionals and excludes the general population. Therefore, future research may explore the perceptions and knowledge of the public about the CSFs of SSC. By examining these limitations and potential solutions, this study can contribute to the wider adoption of SSCs.

6. Conclusion

The importance of SSCs for enhancing quality of life is increasingly recognized. However, the implementation of SSCs is not yet widespread enough. To ensure successful implementation, it is crucial to understand the critical success factors (CSFs) associated with SSCs. This study aims to evaluate and rank the CSFs for implementing SSCs in Abu Dhabi, extract relevant CSFs from scientific literature, and use SQM to examine the relationships between CSFs. Data from 140 industry practitioners in Abu Dhabi were collected to determine the impact of various CSFs on SSC implementation. The CSFs were grouped into four components: PC, GOV, TECH, and MO. The empirical data demonstrate that CSFs have a significant influence on SSC implementation and shed new light on sustainable development in the United Arab Emirates. The study identifies end-user participation, accountability, effective communication, and project team expertise as key factors that motivate SSC deployment. These findings can inform policymakers and academics in developing targeted plans to accelerate the use of SSCs.

CRediT authorship contribution statement

Rahaf Ajaj: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Mohanad Kamil Buniya:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ibrahim Yahaya Wuni:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization. **Omar Sedeeq Yousif:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Data availability statement

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

Conflict of interest statement

The authors have no conflict of interest to disclose.

Acknowledgement

The whole financing for this research endeavor has come from Abu Dhabi University. Fund ADU #: 19300804. The expert responders who took part in the questionnaire survey are all appreciated by the authors. The thoughts and conclusions drawn from this study by the authors may not necessarily reflect those of the respondents or their organizations.

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