Drivers and Barriers for the development of Smart Sustainable Cities

A Systematic Literature Review

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ABSTRACT

The term Smart Sustainable City (SSC) has been gaining popularity due to the growth of initiatives to address urban problems towards sustainable development. SSC can be considered as a combination of sustainable city and smart city, and some variance between the concepts may be expected. As this is a modern term, the literature falls short of studies presenting factors that hinder and/or facilitate the complex phenomenon of SSC development. Therefore, this paper aims to analyse scientific studies to identify aspects that influence the progress of smart sustainable cities. The methodological approach undertaken was a systematic literature review that included 169 papers. The results offer a comprehensive list of 57 drivers and 63 barriers, classified according to five main dimensions of a smart sustainable city, which are the three sustainability pillars (society, environment, and economy), combined to governance, and urban infrastructure. The findings revealed ‘governance’ as the most significant domain for SSC development, and multi-stakeholder engagement as one of the main challenges. This study shows that SSC is not a research field itself, but an interdisciplinary concept, contributing to academics, government, and policymakers for eradicating potential interferences in the development of smart and sustainable cities.

CCS CONCEPTS

• **Applied Computing**; • **Computers in other domains**; • **Computing in government** → *E-government*;

KEYWORDS

sustainable city, smart city, challenges, enablers

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1 INTRODUCTION

The proliferation of smart initiatives brought new terms such as “smart city” and “sustainable city”; the first is related to the use of technology to improve urban services, whereas the second attempts for sustainable development [1]. Some academics have defended the adoption of the term “Smart Sustainable City (SSC)” [2–5], which can be understood as a combination of “smart city” and “sustainable city” [6]. Similarly, Höjer and Wangel [7] suggested that SSC should be seen as an aggregate concept that connects three parts: smart, sustainable and cities, in a way that cities could be sustainable without the use of technologies, or cities could use Information Communication Technologies (ICT) without contributing to sustainable development, but only when the three aspects are combined that we have a SSC. According to them, “A Smart Sustainable City is a city that meets the needs of its present inhabitants, without compromising the ability for other people or future generations to meet their needs, and thus, does not exceed local or planetary environmental limitations, and where this is supported by ICT” [7] (p. 10). A key aspect is that the use of technology in SSC should be as means to achieve better quality of life and long-term impacts.

Research on smart sustainable cities can be considered in its “initial stage” [8, 9] and full of unexplored opportunities [3]. The development of SSCs is a complex phenomenon [10–12] that requires a holistic analysis; however, the majority of previous studies in this domain are focused on the technology side [13]. Furthermore, little effort has been made to investigate drivers, enablers, challenges and barriers for SSC development [6]. Few examples of related previous studies are focused on one region, for instance the identification of enablers affecting SSC development in the Indian context [14], SSC challenges faced in the Arab region [15], and the recent study of Khan et al. [16], which identified critical challenges faced by private and government organizations in Pakistan. Furthermore, there are available studies focused on smart cities drivers and barriers (not smart sustainable cities), as is the work of Guedes et al. [9], which identified potential smart city drivers, and [17, 18], which identified barriers for the implementation of smart city initiatives in India. Nevertheless, remains a need for an extensive and holistic review to outline both enablers and challenges influencing smart sustainable city development.

Considering the lack of studies outlining a synthesis of aspects that influence the progress of smart sustainable cities, the central question that guides this study is: “What are the main enablers and challenges for the development of Smart Sustainable Cities?”. The methodological approach includes a systematic literature review. The enablers and challenges identified in the literature are classified

according to the SSC conceptual model developed by Azambuja, Viale Pereira and Krimmer [6], which represents a smart sustainable city as an interplay of five main domains: the three pillars of sustainability (social, economic and environmental), urban infrastructure and governance.

The remainder of this paper has the following structure: The next section details the methodology implemented in this study; the third section presents the results of this study. The fourth section discusses the research findings and the last section concludes the discussion and explains the limitations of this study.

2 METHODOLOGY

This section explains the methodology of the literature review performed to identify factors that enable or hinder the development of smart sustainable cities (section 2.2) and briefly introduces the SSC conceptual framework (section 2.1) applied to classify the literature.

2.1 Conceptual Framework

This study considers a smart sustainable city a combination of “sustainable city” and “smart city”. The term first term can be understood as a new attitude that balance its goals with the principles of sustainable development [1, 19], it is about people, natural system, learning, social changes and balanced conditions on a long-time horizon [19]. On the other hand, the term smart city is usually related to the use of technology and changes in services based on innovative approaches [19]. Thus, the addition of the word “sustainable” to the term smart city brings the idea that the benefits of smart sustainable city’ initiatives should improve the quality of life now and should also last for future generations.

As suggested by Azambuja, Viale Pereira and Krimmer [6], a smart sustainable city is a territory that is able to balance the three sustainability pillars (social, economic and environment), making use of urban infrastructure and having the governance on the top of the model. In their model [6], the urban infrastructure dimension, which includes urban ICT and physical infrastructure, is set as the ground layer of the smart sustainable city to connect all necessary infrastructure to deliver city services. This base dimension is often referred as the built environment and digital layer of a smart city. In the middle of the model, the three dimensions social, economic, and environmental represent the sustainability of the city; and on the top is the governance domain, which is responsible for the coordination of all city elements to ensure that all domains are being considered to reach sustainability. This comprehensive model shows that a smart sustainable city extends the smart city concept. SSC is an interdisciplinary concept that comprises different domains where technology serves as a means and not as a goal itself. According to a recent study [20], the improvement of quality of life of urban residents and the enhancement of city functioning can be achieved through activities covering the five dimensions suggested by Azambuja et al. [6]. Thus, this model was used in this study to guide the identification and classification of potential challenges and enablers for the development of SSCs.

2.2 Method

The methodological approach used to answer “What are the main enablers and challenges for the development of Smart Sustainable

Cities?” was a systematic literature review, which is recommended when the domain of study demands an association of different academic disciplines [21]. This methodology helps to summarize evidence in an accurate way [22] and is more reliable than traditional narrative reviews in the sense that the literature is selected using a transparent and reproducible process, which increases the methodological rigor and minimizes bias [23]. To accomplish the systematic literature review, it was taken into consideration the recommendations of the new version of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses—PRISMA 2020 Statement [22], which provides updated reporting guidance for systematic reviews. In addition, it was considered the guidelines of Wolfswinkel, Furtmueller and Wilderom [24], which suggest a five-step method for reviewing the literature. The step-by-step method applied in this research consists of the steps described in the following paragraphs and illustrated in Figure 1.

The first step was dedicated to defining the research plan, the inclusion and exclusion criteria. Considering the aim of this review, the author defined the keywords and the set of inclusion and exclusion criteria to be used. As this study aimed to identify aspects related to the development of smart sustainable cities, the term “smart sustainable city” and its variations (e.g., sustainable smart city, smart and sustainable city, etc.) were used. This selection distinguishes the present research from other studies that searched for the word “smart city” (without the word sustainable). The inclusion criteria were determined as academic journal articles and conference papers available online in full-text and published in English, which are relevant to the study aim and to answer the research question. Examples of relevant papers are studies mentioning driving forces, enablers, challenges, barriers, technologies, and tools used (ICT), innovations, and smart governance aspects. The exclusion criteria were defined by publications that did not mention any factors impacting the SSC development or papers presenting insufficient description of the investigation methods or results validation (i.e., weak methodology).

The second step was the search itself. The search task of relevant studies for review was undertaken in May 2019 using Scopus and Web of Science. The query string used in the databases was: (“smart sustainable cit*”) OR (“sustainable smart cit*”) OR (“smart and sustainable cit*”) OR (“sustainable and smart cit*”) OR (“smart sustainability”). The search allowed for instances of the keywords in the article title, abstract and keywords list. Since SSC is a multi-domain field, the journals were not limited to one specific area. Furthermore, neither starting publication date nor end date was introduced in the search. The query resulted in 221 records in Scopus and 193 records in Web of Science, totalizing 414 records. Figure 1 summarizes the literature identification, screening, and inclusion process through the PRISMA flowchart.

The third step was the selection of the literature sample. When doing a systematic literature review, the first step of the selection phase is to look for double items; therefore, the author manually checked the total list of 414 records obtained in the search phase to eliminate duplicates, resulting in 271 unique records. After the identification phase, the screening phase aimed to verify the records according to the inclusion and exclusion criteria prior defined. The document type and the availability online and in English were

Figure 1: Literature search and selection from the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) flowchart.

verified. After removing books, book chapters or book reviews (exclusion reason 1, 39 records), conference reviews/proceeding lists (exclusion reason 2, 10 records), editorials, notes or news (exclusion reason 3, 13 records), and records not available online and in English (exclusion reason 4, 5 records), 204 papers were assessed for eligibility. The full texts of these initially screened articles were then read against the research aim. This resulted in 100 eligible articles. Following the forward and backward method [24, 25], 69 publications were added for a better understanding of the SSC development process. With the inclusion of the additional literature through citation searching, the total number of studies included in the review reached 169 records.

After searching and selecting the sample of articles, they were analysed and classified in papers containing enablers, drivers and/or barriers, challenges, etc. In addition, the drivers and barriers were coded according to SSC dimensions (governance, social, environmental, economic, and urban infrastructure), with the support of the NVIVO Software. If one paper mentioned an aspect of more than one dimension, it was included in more than one category. The SSC conceptual framework presenting the SSC domains and its characteristics (see 2.1) was used as a point of departure to organise the results; however, the scheme was updated and enlarged during the research analysis. Codes were inductively derived throughout the analysis stage, characterizing an iterative process to identify key aspects to consider [24, 26]. Various reviewing cycles were applied, classifying the drivers and barriers into sub-categories.

The last step performed in this review was the structure of the content, or in other words, the writing up and the presentation of the findings in the format of a literature review paper. The findings

were summarized in two tables, one for drivers and one for barriers. Each table presents the list of factors (driver or barrier) coded during the analysis of the paper (classified according to the SSC domain) and their references.

3 DRIVERS AND BARRIERS FOR SMART SUSTAINABLE CITY DEVELOPMENT

This section brings aspects that could facilitate or hinder the development of SSCs. Table 1 lists the 57 drivers and 63 barriers, grouped into the SSC dimensions SSC dimensions: social, economic, environment, governance, and urban infrastructure¹.

The drivers and barriers classified under the social dimension embrace aspects related to people and communities. Authors indicated the importance of the provision of urban services [13, 27–29] such as education facilities to elevate the literacy rate and to generate workforce [30–36]. Community development, promotion of collectivism and volunteering were also mentioned [27, 28, 37]. In terms of barriers, citizens are not aware of what is happening nor of the importance of their participation, consequently, the lack of citizens' participation is a barrier for SSC development. Further, citizens do not trust on government [38, 39], fact that hinder their support to smart initiatives.

The economic factors refer to aspects of financial, innovation, employment, management of resources and related aspects. Innovation ecosystems, and the creation of living and urban labs were highly mentioned by academics. Another enabler is the use of

¹The list of drivers and barriers containing more details and their references is available in Appendice A.

Table 1: Drivers and Barriers for Smart Sustainable City development.

SSC dimension	Drivers	Barriers
Social	Public provision of urban services	Lack of citizen participation
	Innovative healthcare and sanitation facilities	Lack of trust
	Education to elevate the literacy rate	Lack of social awareness
	Accessibility and social inclusion	Cultural diversification
	Social responsibility, informed citizens, knowledge sharing	Citizen's inequality
	Community development, collectivism, volunteering networks	Digital divide
	Participative and engaged citizens	Resistance to change
		Social exclusion and gentrification
		Unavailability of services for different communities
		Lack of connection between technological and social infrastructure
Economic	Innovation, urban labs, Research and Development (R&D)	High cost of urban infrastructure, imbalance of investments
	Crowdsourcing	Lack of funding and investors; short time horizon of investments
	Knowledge and shared-based economy, portfolio-thinking	Volatility of global economy
	Sustainable management of resources, circular economy	Mono-sectoral economy
	Partnership formation, multisector synergies	Competitiveness (local against regional and international markets)
	Promotion of social and human capital	Unbalance between competitiveness and quality of life
	Workforce availability (skilled and non-skilled)	Unemployment, lack of equity access to labour market
	Attract and retain workforce, flexibility of the labour market	Lack of qualified human capital
	Urban attractiveness	Weak Public-Private Partnership
	Tourist attractive projects	Inefficiency of resource management
Environmental	Energy related: renewable resources, saving initiatives, smart systems	Climate change
	Water related: monitoring quality, efficiency of water usage	Growing population, unbalance between liveability and environment
	Pollution prevention and reduction	Increasing resource consumption
	Air pollution monitoring, emission control systems	Scarcity of resources, loss of biodiversity and natural habit
	Smart waste management	Lack of resource sharing
	Recycling	Lack of holistic approach for environmental sustainability
	Availability of environmental standards	Lack of knowledge on how ICT can decrease energy consumption
	Environmental projects and green initiatives	High level of air pollution
	Quality of urban space, land use planning	Inefficient waste management
	Mobility related: efficient transport systems, cycle paths	Traffic density and inefficient public transport system
	Smart building, Responsive Building Envelope (RBE)	Lack of planning; lack of vision and strategy
	Transparency and openness	Lack of project management
Governance	Citizen empowerment, interactive and participatory services, co-production, co-creation, bottom-up approaches	Lack of capacity (HR)
	Information and knowledge sharing, communication channels	Lack of IT knowledge among city planners
	Supportive government policies, political will and synergy	Lack of operational capability
	Urban planning: strategy and vision definition	Lack of capacity building (training)
	Context adaptation, analysis of current situation, flexibility	Structure issues: isolated silos; lack of internal cooperation
	Capacity planning (i.e., infrastructure, cost, and human resources)	Structure issues: complexity of organizational structures
	Clear definition of roles and responsibilities	Lack of alignment, conflicts of interests
	Leader / champion: dedicated organization / person for SSC initiatives	Lack of knowledge and information sharing
	Key Performance Indicators (KPIs) definition; monitoring / assessment	Lack of engagement opportunities
	Collaborative decision-making; participatory governance models	Poor Public-Private Partnership
	Stakeholders' engagement: internal (cross-sector), and external	Centralized decision-making process, top-down approach
	Align and manage conflicts of interests	Political instability and complexity
	Data-driven decision-making and availability of real-time data	Lack of political will and support
	Urban proactiveness for service provision	Lack of transparency and trust
	Data governance: data quality, data sharing and data privacy policies	Lack of regulation and legislation
		Inability of policies
		Multiplicity of policies and programs
		Lack of standards for measuring performance
		Lack of data governance
		Lack of open data, issues for opening data

Table 1: *Continued*

Urban Infrastructure	Physical infrastructure integration	Urban infrastructure deterioration
	Affordable housing facilities, such as water and energy supply	Deficit of technological infrastructure
	Adoption of innovative construction techniques	Lack of infrastructure integration, complexity of networks
	Connectivity, broadband, access to internet facilities	Technological obsolescence, systems failures, infrastructure fragility
	Interoperability and integrated ICT	Lack of systems interoperability and lack of integration standards
	Security verification tools / systems	Lack of systems security, privacy violation
	Advance ICT, intelligent technologies in urban services	Poor quality of ICT-based services
	Smart grid; intelligent energy management systems	Lack of data integration, complexity of opening and linking data
	Use of Geographical Information Systems (GIS)	Lack of data management, huge volume of data
	Data processing: modelling imperfect data; data exchange	Lack of cloud and Fog computing
	Data analytic capacity; Business Intelligence (BI)	Vendor locking
	Internet of Things (IoT)	
	Big Data	

crowdsourcing as an alternative way to foster urban innovation as it helps to generate new ideas serving as an engagement platform. Other perspective of economic enabler is related to an effective management of urban resources, mentioned by Zhang et al. [40] as ‘cleaner production’, which aims to avoid waste and to maximize economic benefits. Moving to the economic barriers, the high cost of urban infrastructure was strongly stressed by academics. In addition, authors criticized the imbalance on investments regarding hard infrastructure (physical, hardware, sensors, systems) and soft infrastructure (capabilities) [2].

Environmental aspects are related to the use of renewable energy sources, smart waste management, land use planning, pollution control and prevention. The literature presents cases of initiatives highlighting the ‘ecologic’ side of SSCs with the potential of using modern technologies for lower resource consumption and carbon emission [41], and the benefits of using renewable energy sources [42]. In terms of barriers, ensuring environmental sustainability and building eco-friendly environment are challenging aims.

Moving to the governance dimension, SSC governance should be transparent [28, 43, 44], make use of open government approaches [28, 45–47] and should empower and engage citizens since the design of (interactive) services [45, 48]. Knowledge and information sharing were also mentioned as good practice [19, 49] to foster open and collaborative environments [45]. Likewise, many papers mentioned the involvement of multiple stakeholders and the creation of partnerships and cooperation. Among the list of governance barriers are the lack of planning, lack of communication, lack of leadership to run smart developments effectively. As a consequence, the uncoordinated implementation of initiatives might result in isolated efforts creating the risk of putting projects on hold due to the lack of resources [28]. Another range of challenges refer to the complexity of organizational structures and political issues. Frequently, the administrative structure of cities is organized in isolated silos (operational nodes) occasioning a lack of internal coordination and cooperation within city’s agencies.

In terms of urban infrastructure drivers, scholars stated that specialized technologies like big data through IoT, and big data processing through AI bring emerging promises for city’s design

and management [50]. Allam and Dhunny [51] mentioned applications of AI that could benefit the development of SSC, such as AI for education, environment, health care, policy, mobility and sustainability. However, in order to benefit from the use of those emerging technologies, cities should have a robust infrastructure of systems and devices that are able to capture, process and spread data within different sources [18, 45, 52], and physical infrastructure integration, optical networks to support the communication of different data centres.

4 DISCUSSION

As seen, the drivers and barriers identified in this study are not exclusive from one or another dimension, confirming the interplay among the SSC dimensions. The literature highlights the “overlap” of dimensions. For example, the barrier “lack of skilled people” can be either classified under the social dimension [15] or under the economic one [44]. Similarly, the barrier “lack of investments in IT training” was categorised [18] as an economic challenge due to the high cost of IT; nevertheless, the lack of capacity (capabilities, skills) is classified in this review as governance issue. Connecting urban infrastructure and governance, authors are concerned with the existing lack of technologically comprehensive human resources. For instance, Yarime [53] highlights the need of creating capacity for data management. The lack of IT knowledge is considered as a capacity issue, thus, is a governance-related aspect. Besides the need of operational IT workforce, scholars mentioned the lack of IT knowledge among public authorities and policy makers [54] in order to help the digital transformation.

The results of this study emphasise the importance of governance for SSC development. Almost all the papers analysed (94%) mentioned at least one governance driver or barrier (63% mentioned drivers and 60% barriers). Some challenges correspond exactly to the lack of an enabler. For instance, some scholars indicated “information and knowledge sharing” as driver for SSC success, whereas other authors underlined that the lack of information sharing results in conflicts of interests and lack of engagement [55]. Another important governance aspect is political instability. One way to

mitigate consequences of this challenge is the definition of a city vision and the creation of a strategic planning for that is not directly associated to any political party [56] in order to have a sustainable (long-term) initiative. Another governance aspect is the use of policies, which must contemplate multidomain aspects related to mobility, health, security, and education [13]; stimulating social inclusion and innovation to drive economic growth [57].

Most studies have a technological focus, due to the “smart” aspect of SSCs. Among the 169 analysed papers, 140 (83%) mentioned at least one urban infrastructure driver or barrier. The results show that the SSC academic literature centres more on ICT than on urban physical infrastructure; however, infrastructure aspects are related. Furthermore, some aspects identified as drivers may cause side effects. For instance, big data can support the design, monitoring and service provision [19]; nevertheless, the city infrastructure should be in line with the use of these technologies, being a challenge.

5 CONCLUSIONS

Through an extensive systematic literature review comprising 169 articles, this study addressed the question of “What are the main enablers and challenges for the development of Smart Sustainable Cities?”. In this investigation, it was possible to identify 57 drivers and 63 barriers that influence the progress of SSC, which were classified according to the main SSC domains (social, environmental, economic, governance, and urban infrastructure). The findings show the nuances of SSC are not generally applicable to smart cities. The addition of the word “sustainable” to the term smart city creates the idea of something that meets the needs of the present without compromising the ability of future generations. Furthermore, this study confirms that SSC is not a research field itself, but a concept that connects different disciplines.

Reflecting the number of identified factors and the number of references mentioning each SSC domain, ‘governance’ can be considered as the most significant domain for smart sustainable city development followed by ‘urban infrastructure’, ‘environment’, ‘social’, and ‘economic’. The findings indicated a relation between many identified drivers and barriers, suggesting that many SSC challenges could be avoided or overcome with good governance practices. Moreover, the SSC development is a complex phenomenon that needs to be addressed in a holistic way by contemplating all SSC domains to generate sustainable impacts.

In terms of contribution, this review contributes to the gap of holistic studies investigating factors impacting the development of SSC offering a comprehensive list of drivers and barriers. Therefore, it has the potential to help different stakeholders, such as decision makers, public administrators, and practitioners in the identification of aspects to consider when developing SSC initiatives that can create long-term benefits.

This study has embedded some limitations. First, the data collection for the systematic literature review was performed in Spring 2019. Nevertheless, the author performed the same search in Spring 2021 to verify if the papers published between May 2019 and May 2021 were mentioning novel drivers and/or barriers that were not included in the initial results. A sample of 20% of those new papers were checked and no expressively new driver nor barrier was found, meaning that the study reached data saturation [58]. Thus,

this data collection limitation does not affect the results of this research, confirming its relevance. Second, the literature search covered only peer-reviewed journals and full conference papers indexed at Web of Sciences and Scopus. Third, the author used a conceptual framework to guide the identification and classification of potential factors that affects the development of SSC, which covers five domains; however, there might be other models that could indicate a different set of factors that were not covered by the selected SSC framework. In addition, the identified aspects were not analysed in detail, and future work could perform a deeper analysis and prioritization of them. The recognized drivers and barriers could be evaluated further to find out their causal relations in smart sustainable city development. Lastly, one aspect labelled as an enabler could also be a barrier when there is a “lack of” such aspect, and this situation may vary considering different contexts.

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A APPENDICES

The full list of identified drivers and barriers and their respective references can be found in the following link:

<https://drive.google.com/file/d/1zKT-GpXMTkEyqULD2s-DFw6W3sYmbCm6/view?usp=sharing>