Sustainable Smart City

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Cities, as dynamic living centers and hubs of production and consumption, play an essential role in the global economy, are major contributors to the world's GDP, and serve as arenas for political and social changes. Effectively managed cities can benefit residents by generating economies of scale through shared amenities, fostering health and well-being. Cities not only leverage industries' creativity and help firms to innovate, but also serve as cultural incubators that determine livability and attract, retain, and nurture the segment of the creative labor force needed to succeed in the new economy. Sustainable Smart Cities have a significant potential to ensure equal access to public services, achieve sustainability and governance transparency, improve livability, and anticipate and mitigate increasingly changing threats.

sustainable smart city | assessment tools | analytic hierarchy process | content analysis

1. From Sustainable Development and Smart City to Sustainable Smart City

At its inception, the paradigm of Sustainable Development (SD) emerged in response to the increasing environmental and social challenges created by the traditional economic development model. SD seeks to develop a sort of equilibrium between the development dimensions (environmental, economic, social, and cultural). The "*World Commission on Environment and Development*" (WCED) originated the most widely accepted definition of SD in its 1987 *Brundtland* report "*Our Common Future*" [1], stating that SD is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Then, the concept evolved gradually, raising awareness of anthropogenic impacts on the environment and society, and creating a dynamic for saving the planet. This process culminated in 2015 with the initiative "*Transforming Our World: The 2030 Agenda for Sustainable Development*", an action plan of 17 sustainable development goals (SDGs) to end poverty, protect the planet, and ensure peace and prosperity for all by 2030. SD relies on a set of principles that help to achieve a more sustainable world [2][3]: (1) *intergenerational* as well as *intragenerational equity*, (2) *stakeholders' effective participation* in decision-making processes, (3) *integration* and a holistic approach to environmental, economic, social, and cultural dimensions, and (4) the principle of a *cautious approach* to minimize damage. Nevertheless, despite the brighter future it promises for humanity, the concept of SD has not been without controversy. As stated by Huovila et al. [4], the concept has been described as obsolete in today's digitalized society. Also, Barkemeyer et al. [5] considered that urban SD has been incorporated into a business-oriented agenda that has weakened the concept.

On the other hand, in the past decade, especially since the adoption of the SDGs, approaches to urban issues have gradually converged on, and conveyed principles of SC that have come to dominate the scene among scholars, city planners, and practitioners. Cities' visions, goals, and priorities for becoming smart may differ depending on local contexts; however, the use of ICT to improve urban operations and service delivery appears to be a common denominator. The concept of SC can be traced back as early as the 1960s and 1970s when the American "*Community Analysis Bureau*" was collecting data and directing services in Los Angeles using databases, aerial photography, and cluster analysis [6], but the term "Smart City" appeared a decade later, coined by the American author E. Diller [7]. In the 1990s, the first virtual digital city was created in Amsterdam (De Digital Stad (DDS)), providing online access to information and services, and in the 2000s, IBM and Cisco launched separate initiatives to promote SC solutions based on ICT infrastructure and data analytics [8].

Various definitions have been proposed as to what constitutes an SC, and they continue to (co-)exist throughout the urban sphere, feed the scholarly literature, and have relevance to the policy and practice of those who study or manage cities. IBM [6], The European Union [9], and Cisco [10], each have its definition. However, and to a large extent, these definitions are ICT-oriented and refer to a city that uses data collected from various sources, devices and citizens, to monitor and manage urban systems and efficiently deliver urban services, relying on Information and Communication Technologies (ICTs) capabilities. The reference to ICT is also in line with early attempts to define the concept, such as Eger [11], Washburn et al. [12], Harrison et al. [13], Batty et al. [14], Lazaroiu and Roscia [15], Lombardi et al. [16], Bakıcı et al. [17], Mulligan and Olsson [18], and Townsend [19]. Other earlier studies, such as the work of Shapiro [20], had broadened the scope of smartness to include its outcomes, such as quality of life, while more recent research had complimented the focus by highlighting sustainability and services to the citizens [21][22][23][24][25][26][27], as did Caragliu et al. [28], when they underlined that for a city to be smart, investments in human and social capital, as well as traditional and modern ICT communication infrastructure, should support sustainable economic growth and improved quality of life, through participatory governance. Similarly, after reviewing the published literature on smart cities from 1993 to 2012, Cocchia [29] enumerated the key attributes of a smart city as (a) *global*,

(b) *intelligent*, and (c) *knowledge-based*. Nevertheless, despite this profusion of definitions around the SC model, Hamman et al. [30] reported no clear consensus on what constitutes an SC.

Over time, the concept of SC has evolved, influenced by various historical milestones related mainly, but not only, to advances in visible or embedded technologies. Currently, a set of core principles serve as a guide to achieve SCs: (a) *Citizen-centered* process; (b) *Innovation* [28]; (c) *Integration* [31]; and (d) *Sustainability.* Technological advances can help foster long-term urban growth, and according to many scholars, the use of ICT to plan or manage cities is at the root of the SC model [32][33][34].

The SC model has also been criticized on several levels. Hollands [35] pointed out a competitive form of urban “entrepreneurialism” that compromises citizens’ participation in an SC model dominated by corporate and entrepreneurial governance. Furthermore, in a panel data analysis of 15 UK cities, Yigitcanlar and Kamruzzaman [36] found a lack of contribution of SCs in achieving tangible sustainable urban outcomes. Other authors, such as Patrão et al. [37], reported contrasts between the rise in the implementation of SC projects and a persistent lack of a common and acceptable definition for the SC concept, yet noticed a degree of consensus on the substantial role of technologies in shaping urban development. Earlier, Temenos [38] had criticized the idea of SCs as being a tool to legitimize growth-oriented policies, and according to Kambites [39], the concept has also been “abusively” adapted to boost neoliberalism’s attempts to advocate for the compatibility of economic growth with environmental protection. It can be easily seen that in many other circumstances, smart city projects have also been described as a target of urban branding to restore the image of declining cities in times of citizen involvement and control over governmental action, as well as a way to attract foreign finance and corporate investments.

Despite these criticisms, the literature underscores the importance of attaining advanced levels of sustainability and smartness for the future of cities, and in response, the hybrid concept of SSC has arisen and gained prominence [27][40][41] to ensure that SC solutions are aligned with sustainability, and conversely, that sustainability considerations are in harmony with the needs of modern, highly digitalized cities. Over the years since the economic, environmental, and sociocultural concerns were set as a shared perspective for SD, digitalization and innovation have gained equal importance and visibility as core requirements of sustainable communities. After examining more than 100 definitions of smart cities, the International Telecommunication Union (ITU) proposed the concept of “Smart Sustainable Cities” [42]. It argued that an SSC would benefit from the use of ICT to achieve a better quality of life and increase its competitiveness and the effectiveness of urban services [43]. The conceptual difference between Smart Cities and Sustainable Cities would be that SCs use intelligent technologies to achieve sustainability [44].

2. Sustainable Smart City Indicators

Since the Rio Earth Summit in 1992, several assessment tools with different sets of indicators have been developed, relying on many data sets to monitor, analyze, and provide solutions to the challenges of the complex aspects of SD. Currently, this area is of immediate relevance to the pressing need to achieve the SDGs and is, thus, of particular interest for research and practice. On the other hand, factors such as differences in culture, the structure of the economic systems, and the nature of the administrative and political institutions, all contribute to local success. Consequently, the indicators to measure or assess sustainability and smartness would be influenced by local factors and might differ or be differently perceived from one community to another. Nonetheless, several measures considered core requirements in spheres such as economics, technology and innovation, governance, socio-cultural environments, quality of life, and infrastructure, remain critical across most cities and communities. This section summarizes the literature on the SSC indicators used as metrics tools. The following material, which investigated a large spectrum of these sets of indicators, has been portrayed chronologically from the most recent to the oldest for the sake of convenience.

Pandey and Albert [45] reviewed commonly used standards of community sustainability, proposed by several international evaluation systems, associations, special interest groups, and researchers. The authors debated the selection of indicators for building a system to measure and monitor a region’s progress. The research classified the indicators into the six factors suggested by the “*Political, Economic, Social, Technological, Environmental, and Legal* (PESTEL)” analysis. It noted an over-representation of indicators monitoring environmental factors (in older evaluation systems) against indicators across the PESTEL factors (in newer evaluation systems). The research highlighted, in particular, the gaps in measuring the progress in fields such as *Governance*, *Technology*, and *Innovation* of a city. Adopting a different point of view, Giffinger and Kramar [46] questioned “How might the use of indicators promote smart urban planning in a place-based approach?”. They examined the policy implications of the European SCs’ approach. They agreed with previous studies, such as Komninos and Mora [47] and Cocchia [29], that the literature was fragmented, resulting in “heterogeneous understandings [and definitions] of an SC”. In a critical analysis, Sharifi [48] examined 34 tools for SC assessment. The designated tools were gauged using a comprehensive multi-criteria approach. The research findings pointed to a lack of success of these tools in addressing criteria related to “stakeholder engagement, uncertainty management, interlinkages, and feasibility.” Moreover, the author noticed an imbalanced distribution of indicators favoring dimensions such as “mobility”, “economy”, and “environment” at the expense of “people” and “data”, which are otherwise crucial for effective SC deployment. Compared with others, the originality of this research is that it highlighted a major shortcoming of the analyzed tools: the limited use of modeling and scenario-making techniques in the face of uncertainty. Lombardi and Giordano [49] reviewed the UN-HABITAT's *Global Urban Indicators Database* and identified a blend of quantitative indicators, qualitative checklists, and hybrid performance indicators. They also inventoried more than 150 systems of city indicators covering diverse geographical and thematic criteria, in addition to a variety of methods that aimed to evaluate sustainability in the built environment.

Similarly, Stratigea et al. [50] investigated some global approaches for assessing the performance of SCs. Their findings enabled the identification of a city-specific set of sustainability indicators. They perceived the selection of adequate indicator sets as an intriguing issue that has triggered confusion, prevented proper monitoring of urban sustainability projects, and even as a source of mistrust and opacity, leading to support for pre-defined policy directions and decisions. Using comparative analysis, Huovila et al. [4] developed a "taxonomy" to evaluate seven standards (including 413 indicators) for SSC. They evaluated each indicator against (a) five categories of urban sustainability and smartness, (b) ten domains/dimensions, and (c) five indicator types. They pointed out two predominant streams of indicators, (1) those aimed at evaluating the implementation of SC approaches, and (2) those designed for sustainability assessment, and also reported a scarcity of scientific literature on "standardized frameworks of city indicators". However, this shortage appears to contrast with the wide range of indicator frameworks utilized to assess urban smartness and sustainability revealed by other studies, such as the earlier works of Albino et al. [51] and Sharifi and Murayama [52]. In an attempt to organize SC indicators in thematic areas, Petrova-Antonova and Ilieva [53] conducted a survey and examined a set of performance and sustainability indicators for smart cities. They considered the selection of adequate indicator sets as a challenging task.

Caird [54] introduced a different perspective for a typology of the indicators: (a) Assessment Models, such as the "*Smart City Maturity*", the "*Smart City Reference*", and the "*European Smart Cities Ranking*"; (b) Assessment Tools such as the "*Smarter City Assessment*", the "*Smart City Index Master Indicators*" framework; and (c) Assessment Indexes such as the "*Ericsson Networked Society City*" and "*Cities of Opportunity*". Anand et al. [55], in turn, identified a set of 20 sustainability indicators for designing SCs in developing countries and determined their relative importance using fuzzy and fuzzy-AHP methods. Albino et al. [51] presented other tools, such as the "*Smart Ranking Systems*" developed by the University of Vienna, the "*Intelligent Community Forum's Smart 21 communities*", the "*Global Power City Index*", the "*Smarter Cities Ranking*", the "*World's Smartest Cities*", the "*IBM Smart City*", and the *McKinsey Global Institute* rankings.

Several other studies have also approached urban smartness and sustainability through an indicator-based lens for benchmarking global cities, as Phillis et al. [56] reported. The spectrum of these approaches includes the UN-HABITAT "*City Prosperity Index* (CPI)", the "*Cities in Motion Index* (CIMI)" published by the IESE Business School, the "*Global Power City* Index" mentioned by Ichikawa et al. [57]; and the "*Sustainable Assessment by Fuzzy Evaluation Index* (SAFE)" ([56]). These studies aimed to benchmark global cities by employing up to 77 weighted indicators and different aggregation methods.

In a systematic literature research, Purnomo and Prabowo [58] reviewed 30 studies from four sources (Science Direct, ACM DL, IEEE Xplore, and Google Scholar). They identified six sustainability dimensions (18 indicators) as the most frequently used. Likewise, in a review of environmental assessment tools for sustainable urban design, Ameen et al. [59] scrutinized the well-known tools rating the sustainability of urban areas (*Building Research Establishment Environmental Assessment Method for Communities* (BREEAM), *Leadership in Energy Environmental Design* (LEED), *LEED for Neighborhood Development* (LEED-ND), and *Comprehensive Assessment System for Built Environment Efficiency* (CASBEE)), in addition to other sustainability assessment tools for urban design and development, such as the "*Pearl Community Rating System* (PCRS)" and the "*Global Sustainability Assessment System* (GSAS)". They highlighted a discrepancy in the global sustainability assessment tools in local and international contexts. Castanheira and Bragança [60] studied how the sustainability assessment tool "*SBTool^{PT}-UP*" has evolved from the building level to the broader built environment, providing an eloquent example of how the need to assess sustainability at the urban and regional levels has led to adaptations of tools initially designed for the building level. This example also demonstrates a scale shift in the approach to sustainability and illustrates the extension of the concept from a simple addition of many sustainable buildings scattered around the city to an SC as a whole, as well as how the emphasis of the sustainability assessment tools has extended from buildings to urban operations.

Regarding the significance of the factors considered by the assessment tools, the scientific discipline perspective appears to be an essential factor affecting the focus, which may range from the big data questions described by Laurini [61], to governance considerations, as reported by Meijer and Bolívar [62], and from issues related to technical innovations, as discussed by Schaffers et al. [63], to those associated with economy and sustainability, as stated by Caragliu et al. [28]. Nam and Pardo [64], have previously identified human, technical, and institutional factors as critical for SC deployment.

Most of this abundant literature is more suggestive of a focus on inventory, examining the significance of the addressed issues, investigating through an indicator-based lens for benchmarking cities, etc. Considerable research has been conducted on many aspects, but the objective of streamlining the decision-making process by prioritizing sets of indicators remains a relatively unexplored aspect.

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