The Sustainability of Smart City

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The sustainability of smart cities involves more than the environmental dimension; it encompasses a series of criteria that should be used to define actions and strategies for urban development, e.g., electricity and water consumption, transportation systems, waste management, security, technology inclusion, and sociocultural development, among others.

sustainability measurement smart cities quality of life government mobility economy

1. Introduction

The idea of smart cities has attracted growing interest in the global agenda in the last two decades. The first definitions of smart city emerged after the 1990s as a reflection of the policies different countries adopted to respond to the consolidation of the Information and Communications Technologies (ICTs). Smart cities are technologically modernized territories that, based on techniques supported by smart computing, solve social, economic, and technological issues, which can be seen in the services and infrastructures they develop for their citizens [1].

The progress of ICTs and the changes their introduction has produced in societies have not been in vain because, as a result, new perspectives for the development of the territories have been reconsidered, not only in economic but also social terms. Therefore, in smart cities, the ways citizens interact with the government, the territorial security policies, and even the offer of health care services and the mechanisms to control and monitor diseases have been redefined [2].

In fact, the concept of the smart city has become a key tool that multiple authors have used to address the urban sprawl some countries have experienced in recent years, as well as the consequences derived from this sprawl (e.g., environmental damages). Some models indicate that smart cities should make a contribution at several levels: economic (with innovation and productivity in communities), social (community wellbeing), governance (planning and accountability), and environmental (accessibility and sustainability) [3].

The growth of territories brings more needs and social demands. For the ruling class, this poses a continuous dilemma between satisfying their stakeholders' (citizens') needs and protecting the environment. Thus, it forces them to promote innovative actions that ensure a smart conservation of their resources, that is, adopting sustainable practices [4].

In that sense, sustainable development has been understood as a multidimensional concept supported by the intersection of social, economic, and environmental dimensions. Sustainable development, although discussed since after the Second World War, only gained relevance in the global agenda after the Brundtland Report, where it is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [5].

Undeniably, sustainable development gained further relevance after 2015, when the General Assembly of the United Nations (UN) adopted the 2030 Agenda for Sustainable Development in order to transform the reality of the world, especially that of historically marginalized countries. The Agenda is composed of 17 goals divided into five areas: people, planet, prosperity, peace, and partnership [6].

It was defined based on the premise that ensuring poverty eradication requires not only actions regarding economic development but also environmental protection, the improvement of health conditions and education, and fighting historic gender inequality [7]. There are 17 goals in the Agenda: (1) No Poverty; (2) Zero Hunger; (3) Good Health and Well-being; (4) Quality Education; (5) Gender Equality; (6) Clean Water and Sanitation; (7) Affordable and Clean Energy; (8) Decent Work and Economic Growth; (9) Industry, Innovation, and Infrastructure; (10) Reduced Inequality; (11) Sustainable Cities and Communities; (12) Responsible Consumption and Production; (13) Climate Action; (14) Life Below Water; (15) Life on Land; (16) Peace, Justice, and Strong Institutions; and (17) Partnerships to achieve the Goal [8].

2. Sustainable Development and Smart Cities

2.1. Sustainable Development

The definition of sustainable development has changed over time, and has been shaped by different actors interested in the topic such as the government, the business sector, the academy, and civil society [9]. It has been criticized, but it is considered a global issue in the context of the new needs of modern societies. Although it has been addressed throughout history, this concept was consolidated after the Brundtland Report in the 1980s, in which it was defined by the confluence of environmental, economic, and social variables. The guiding principle of sustainable development is meeting human needs while protecting the current and future availability of resources [10].

In this sense, sustainability has been defined as an entity’s ability to maintain itself over time. Other approaches in the scientific literature have defined the concept as a dynamic of equilibrium between the satisfaction of human needs and environmental protection; this is in line with the contributions of the Brundtland Report [11].

Other authors have referred to the growing relevance of sustainability in global agendas, which is reflected in the policies and programs several governments have adopted. They involve social, economic, and populational elements, as well as access to basic services (e.g., drinking water and health care) and energy use [12].

The importance of studies about sustainability is justified, among other reasons, by the accelerated demographic growth and the demand for resources that it implies; urban development and migratory movements toward big cities; and, finally, the growing energy consumption of different social actors (i.e., households and the productive sector). There is no doubt that the operation of big transportation services, for instance, depends on energy, and this clearly poses huge challenges for environmental sustainability [12].

Although smart technologies can act as enablers in the fulfillment of the Sustainable Development Goals (SDGs), two aspects should be taken into account: (1) the research community and the industry have common interests and self-interests in publishing positive results; and (2) if harmful consequences on the environment (i.e., the SDGs in the Environment group) are found, long-term research should be carried out to assess their long-term impact on equity and fairness [13].

However, although sustainability is increasingly important (e.g., its place in the 2030 Agenda), some authors claim that a lack of axiomatic foundations in this field results in the confluence of multiple theoretical positions. Some of those positions refer to the characterization of complex dynamic systems and the management of finite natural resources available (e.g., the capacity of the biosphere to obtain pollutants). This management involves strategies that integrate environmental, social, and economic aspects and should be based on the results of sustainability assessments (focused on recovery and evolutionary processes) to successfully achieve sustainability. Therefore, the discussions about this topic still need new contributions in order to suggest practical applications. Sustainable development clearly reveals a globalized interest in producing a better quality of life for people, thus achieving the sustainability of the human system [14].

2.2. Smart Cities

As a result of the growing incorporation of Information and Communications Technologies (ICTs) into societies, new concepts have emerged to represent the current dynamics of life. Smart cities are new types of organizations within specific territories based on urbanization and digitization processes aimed at promoting productivity, competitiveness, and global positioning, among other aspects [15].

In their territorial dynamics, smart cities integrate six concepts: (1) smart economy, with high levels of innovation; (2) smart mobility, based on the adoption of sustainable and eco-friendly transportation systems; (3) smart environment, measured as the adequate management of natural resources; (4) smart communities, based on community training and the development of key skills for innovative ecosystems; (5) smart life, a dimension that can be measured using social indicators that reflect the quality of life of citizens; and (6) smart governance, from the standpoint of the supply of goods and services by government agencies and transparency in public administration [15].

The diversity of positions found in the scientific literature reveals the way ICTs are used to promote new constructs of cities. Smart cities have been called digital cities, information cities, knowledge-based cities, and ubiquitous cities, to mention a few. Therefore, the disciplines that study this topic are increasingly different but are closely

related to the achievement of the UN SDGs [16]. Consequently, we checked different academic sources to find some key definitions of this concept, which are reported in **Table 1**.

Table 1. Theoretical definitions of smart city.

Author	Year of Publication	Definition of Smart City
Harrison et al. [17]	2010	Smart cities connect the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city [17].
Caragluiu et al. [18]	2011	A city is smart when it invests in human and social capital and traditional (transportation) and modern (ICTs) communication infrastructures to boost sustainable economic growth and generate a high quality of life, with a rational management of natural resources through participatory governance.
Antrobus, Derek [19]	2011	The emphasis of smart cities is on the low-carbon economy. For that purpose, they apply policies focused on eco-friendly modernization, which may reduce the greenhouse gas effect and help to identify potential combined energy sources that involve local development.
Chourabi et al. [20]	2012	The smart city tag is a diffuse concept that is not always used consistently; it may refer to a high-performing progressive city.
Bouskela et al. [21]	2016	Smart cities put people at the center of development, incorporating ICTs into urban management, and use these elements as tools to stimulate the formation of an efficient government that includes collaborative and citizen planning processes.

Undeniably, the concept of smart city is related to sustainable development, so much so that the term sustainable city has also been widely studied. As a result, many cities in the world have set themselves the objective of forming the backbone of a large and intelligent infrastructure. Thus, this concept has become a vision, a manifesto, or a promise that, according to Trindade et al. (2017), constitutes the twenty-first century's sustainable and ideal city form based on technologies [22].

2.3. Evaluation of Smart City Sustainability

Different models can be used to evaluate sustainability; some of them focus on certain aspects more than others, which is valid depending on the field of expertise or approach under evaluation.

The concept of a smart city has become more relevant due to the current global interest in leading societies in a sustainable manner and because people's actions are having an increasing effect on the planet. The utilization of resources jeopardizes not only the sustainability of future generations but also the sustainability of the present generation, causing serious problems that go beyond the environmental sphere, and also involve social, economic, and political aspects.

For instance, different are the report approaches and dimensions that should be evaluated when sustainability and smart cities are discussed. The environmental approach integrates controlled urban sprawl strategies to affect biodiversity as little as possible, pollution controls, the rational use of resources, and renewable energy technologies. In turn, economic approaches are closely related to city development, where industrial development is fundamental for a good perception of development [23].

Institutional development and social matters are more integrated, making citizens more important and including other points of view and social and cultural dynamics that are essential to discuss sustainable and diverse development. The technological aspect has played a vital role in recent years because the new information and communication technologies are indispensable for smart cities and are a common denominator of the solution to their problems. These approaches have a clear relationship with this study, where these aspects are necessarily framed for a comprehensive evaluation of the sustainability of smart cities.

Sustainability is evaluated using quantitative and qualitative indicators on different spatial scales, i.e., from a building to a neighborhood, city, or urban area. The analysis can also include materials, energy, and air quality as individual aspects, and even transportation planning, community development, social wellbeing, governance, and innovation. Therefore, a wide range of aspects should come together to evaluate sustainability as a whole [23]. Several countries have developed different types of evaluation to produce a more balanced assessment of the environmental, social, and economic dimensions and to draw a bigger picture to analyze.

The BREEAM (Building Research Establishment Environmental Assessment Methodology) certification systems are the first of their kind regarding building construction and planning community development because they place more emphasis on environmental and sustainability issues [24]. In turn, the CASBEE-UD method, developed by the Japanese government and academy, is focused on sustainable and efficient development based on design and planning [25]. The LUD includes urban development aspects and integrates security, natural resource management, and efficiency in transport and construction [26]. The Green Building Index (GBI) emphasizes water and energy consumption, the protection of natural ecosystems, the development of transportation systems, employment generation, and entrepreneurship. The IGBC, developed in India includes, in addition to city planning and land use, innovation and technology [27]. Note that many of these tools, used around the world to evaluate sustainability, have different approaches. Most of them present similarities with respect to the technical aspects of space planning, construction, and design, as well as purely environmental aspects as part of green indicators, but few include social or political aspects as fundamental components of sustainable development. Hence, it is important to have tools that integrate these aspects in order to support cities and their development (an essential part of their growth) based on economic and social factors. Such tools should bring together sustainability and more attention to the dynamics of the population and its well-being [28].

Many of the experts agreed that Medellín should work toward the satisfaction of basic needs, which include everything related to decent housing, access to utilities, average educational attainment, households covered by basic health insurance, and employment that enables individuals to meet many of said needs. This can be difficult to achieve, but the first step is articulating all these components. In addition, we should not forget the technological

component because it enables governments to manage data and companies and citizens to control their resources, all in an effective and safe manner.

Smart cities usually focus on technological development and innovation (central points that determine their classification as smart) and favor the use of technologies to deal with different problems and offer opportunities [29]. Technologies are part of the construction and design process of smart cities and are used to provide services to citizens [30]; furthermore, they may generate sustainability. Although some authors disagree with the idea that sustainable development is a consequence of the implementation of new technologies [31], others claim that the latter can address important issues, such as access to education, improved information systems, and transportation, as well as security solutions that promote human capital training and create jobs [29][32][33]. In another context it is concluded that aspects such as income level, educational attainment, and location in Latin America (specifically) are positively related to the level of city smartness. Thus, cities in countries where information and communication technologies are more developed attain higher levels of city smartness [34]. Employment can also be integrated to improve this level because it is important for the sustainable growth and progress of cities.

Currently, there is no satisfactory explanation of the transformation of cities into smart cities, but it implies commitment and prospective vision to be successful. It also requires time and the characterization of efficient governance models that include a public–private contribution as well as that of citizens. In addition, this transformation involves dimensions that cities can improve to be more efficient and competitive, facilitating new synergies and ensuring the interoperability of their operations and services, which results in a better quality of life for their inhabitants.

Therefore, eight variables were excluded: (1) inclusive innovation and ICTs, (2) competitiveness and territory, (3) energy, (4) social cohesion, (5) environment, (6) water and gas, (7) e-commerce, and (8) communications. They were not excluded because they are not important but because, in this study, we selected different variables to create a more detailed profile of the city under analysis here. As a result, the evaluation herein propose is focused on six dimensions: (1) government, (2) mobility, (3) sustainability, (4) people, (5) economy, and (6) quality of life.

Although the definition of smart city has been widely disseminated and studied in recent years, a great deal of the progress in this area has been theoretical and has been made by the adoption of qualitative approaches. In more practical terms, smart cities require technology in the form of network infrastructure, which translates into a connected, data-driven society. In addition, they require technological mechanisms to improve competitiveness and support their communities, thus generating a better quality of life for their residents. Therefore, future research should examine more real and specific aspects of the dynamics of cities.

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