Smart City Assessment Tools

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Today's cities are estimated to generate 80% of global GDP, covering only about 3% of the land, but contributing to about 72% of all global greenhouse gas emissions. Cities face significant challenges, such as population growth, pollution, congestion, lack of physical and social infrastructures, while trying to simultaneously meet sustainable energy and environmental requirements. The Smart City concept intends to address these challenges by identifying new and intelligent ways to manage the complexity of urban living and implement solutions for multidisciplinary problems in cities. With the increasing number of Smart City projects being implemented around the world, it is important to evaluate their strengths and weaknesses for their future improvement and evolution track record.

smart cities | assessment tools | key performance indicators | sustainability analysis | energy and environmental impacts | climate change

1. Introduction

Today's cities face significant challenges, such as increasing population, pollution, congestion, resource usage, lack of adequate physical and social infrastructures, sustainable economic growth, and increasingly stricter energy and environmental requirements [1][2].

According to the United Nations [3], more people live in urban areas than in rural areas. In 1950, only 30% of the world's population was living in an urban environment, but in 2018, this number increased to 55%. In 2030, it is expected to increase to about 60% [4] and by 2050, the projections point to about 68% of the world's population being urban [3]. The United Nations [3] states that *"the growth in the urban population is driven by overall population increase and by the upward shift in the percentage living in urban areas"*. Together, these two factors can add about 2.5 billion to the world's urban population by 2050, with almost 90% of this growth happening in Asia and Africa [3]. The urbanization process is occurring at different rates, being considerably faster in developing regions than in the developed ones. Africa is expected to be the fastest urbanizing region and according to Joint Research Centre [5], in the last 25 years, the urban population has more than doubled in almost all countries across sub-Saharan Africa, although meanwhile, in many parts of North America and Europe, the urban population has been declining. In 2016, there were, globally, about 512 urban centers with at least 1 million inhabitants and 31 megacities with over 10 million inhabitants [6]. By 2030, these numbers are projected to increase to 662 urban centers and 41 megacities, most of which in developing regions [6].

Nowadays, cities are estimated to generate 80% of all economic growth [7], covering only about 3% of the land, but producing about 72% of all global greenhouse gas emissions [8]. All the continuous population growth, and especially in urban areas, put a lot of challenges in the design of cities and exceptional sustainability challenges, both on infrastructures and the environment [9].

The development challenges of cities have attracted many interdisciplinary fields of study. Computer Science is one of the multiple fields addressing city development challenges. The interest of Computer Science began at the end of the 20th century when cities were idealized to become a network of computers and other electronic based devices [10]. Nowadays, cities are composed of even more complex systems in constant evolution, in which the combination of multiple research areas is needed in order to overcome the arising endless challenges [10]. In order to make cities and communities more inclusive, safe, resilient, and sustainable, as per the "Sustainable Development Goal 11" of the 2030 Agenda for Sustainable Development [11], it is crucial to understand the key trends in the future of urbanization [4], and to evaluate city growth development and implementation measures to fulfill the multi-dimension human and sustainable requirements.

The "Smart City" concept is intended to address the referred challenges by identifying new and smart ways to manage the complexity of urban living and implement solutions for multidisciplinary problems ranging from energy consumption, resource management, environmental protection, security, quality of life, the efficiency of urban operation, and the availability of a wide variety of services [9][12][13].

The estimated number of smart city implementations varies depending on the definition and extent of the elements included in the analysis. A Navigant Research global market report [14] estimated that in 2017, there were more than 250 smart city project implementations in 178 cities worldwide. Europe is the top-performing geographical area with 12 cities ranking among

the top 25 smart cities ranked by the IESE Cities in Motion Index 2018 [15]. Europe is aiming to have about 300 smart cities by the end of 2020 and India plans to build about 100 smart cities by 2022, impacting a population of almost 1 billion people [16].

"Smart City" as a new research concept began in 1992 with the book entitled *"The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks"* [10][17]. Since then, this research area has not only attracted different research areas, but also many stakeholders, from governmental organizations to industries and social society, supporting the growing interest of the "Smart City" concept, within the global sustainable development framework.

According to Mora [10] the "Smart City" research established itself as a new scientific field in the year 2009, but despite all the growing number of publications, the concept is far from having a clear and established definition. Many definitions for the concept have been developed, but so far none has been commonly accepted by the scientific community. It is common to see different interpretations according to the context of the publications [13][18]. The absence of such a definition has been pointed out in several publications, namely [1][10][19]. According to the bibliometric analysis of the literature published between 1992 and 2012 performed by Mora [10], there is a tendency among publications to differentiate themselves, being difficult to acquire a common agreement.

Some publications mostly see Smart City as a technological innovation whereas others see it as social innovation. There is the idealization of a Smart City being supported by a technological combination of different IoT devices forming a wireless sensor network (WSN), for numerous control and monitoring applications fields namely for utilities, security, asset tracking, and smart metering [20]. The bibliometric analysis of the literature developed by Mora [10] points out that *"researchers seem to agree in picturing the smart city as an urban environment in which an ICT-driven approach to urban sustainability is activated"*. The same analysis states that there are although different research paths being followed. The two most cited groups of publications describe the smart city as a more techno-centric approach and the other, one of the most cited and influential documents in the area published between 1992 and 2012, Giffinger [21], as a balanced combination of human, social, cultural, economic, environmental, and technological factors [10]. Technology should be seen as a means to achieve the outcomes of a Smart City implementation according to the needs of its location (environment, energy, people, business, governance, etc).

The Smart City concept is still evolving and there is not yet a commonly accepted worldwide definition, but it is quite clear that Smart Cities leverage information and communication technologies to enhance service levels, citizen well-being, sustainability, and economic development. Expanding the Smart City concept will, for instance, improve the existing infrastructures, increase the digitalization and integration of facilities and services, expand the use of collaboration tools and automated service management platforms, increase the safety of citizens and transportation, making cities more attractive for stakeholders, and living up to citizens' expectations. According to an OECD recent report [22], when well connected with inclusive growth objectives, Smart City implementations can, besides many other advantages, offer powerful tools to support the shift from in-person to remote service delivery, mitigating the fallout of the crisis on urban residents and businesses, including the most vulnerable ones, and empower new forms of local governance. However, the same report states as a possible threat to society the "increased inequality among digitally marginalized groups" and "possible abuse of citizen data, privacy and safety".

Different and distinct Smart City concepts and architectures have emerged during the past decades, but all of them visualize it as being composed of different inter-related components, such as data, economy, people, governance, mobility, environment, and living [13][23]. All of the components are related to different aspects of urban living, such as communication, industry, education, e-democracy, logistics and infrastructures, efficiency and sustainability, security, and quality [23]. All this diversity of components and related aspects has attracted multi-disciplinary approaches and science fields to the Smart City developments, which has contributed to the enrichment of scientific knowledge and increase and scale-up of innovative technology developments.

Despite all the different research paths and lack of commonly accepted definition in the trending Smart City concept, one point is clear; the impact evaluation of Smart City implementations is extremely valuable and strongly needed. Every impact evaluation has the principle of permitting the characterization of achieved levels of performance according to a certain target goal. This is crucial for the planning of the city further developments and upgrades, to assess the strengths and weaknesses, for comparison with other implementations and to inform the different interested stakeholders about the implementation status.

2. Smart City Concept

As already mentioned, in the literature, different expressions can be found referring to similar concepts of "Smart City". The use of combined wordings can also be found, suggesting or definition new concepts, sometimes for differentiation purposes, like for instance the "Smart Sustainable City" concept [24]. Although sometimes not exactly being in the same focus, the use of all these different expressions has been creating terminological confusion [25][26][27]. Today, "Smart City" is probably the most

widespread and accepted wording among citizens, media, investors and companies, and public authorities. It is being used by public authorities and the business sector, as it is a buzz word understandable by most of the targeted audiences [24].

According to Grabys [28], references to Smart City similar concepts can be traced back from the 1960s, when the literature refers to "informational or cybernetically planned cities" and after that, in the 1980s, when references appear to the "networked cities" or "computable cities". The Smart City concept was introduced in 1994 [29]. Later, by 2010, the European Union (EU) began to use the "smart" wording to refer to sustainable projects and actions related to the urban environment [29]. With the appearance of Smart City project implementations supported by the European Union (EU), the interest regarding the subject began to increased significantly [30].

The literature review performed in 2014 by Mosannenzadeh [31], showed that the concept of Smart City was being developed in three main areas: Academic, Industrial, and Governmental, creating different points-of-view by each domain area. At the time, it was pointed out that there was no common definition for the concept and that the disparity of wordings used in different definitions was a sign of controversy in the concept [31]. Nowadays, and despite all the growing number of publications since then, there is still not yet a common and acceptable definition for the Smart City concept, although researchers seem to agree in the significant contribution of the use of technologies for urban development [10][31].

However, there seems to be huge differences and confusion between the concept definitions and what actually is being done in real-world implementations and even in the scope of the main definitions for most reputed international institutions. The literature refers to "Sustainable City" as being the umbrella where other concepts like "Smart City" are under. "Sustainable City" is referred as including a harmonized integration of social, economic, environmental, and institutional aspects, whereas "Smart City" is pointed out as having the main goal of improving the sustainability of cities through the application of ICT, the collaboration of key stakeholders, and integration of domains [32]. On the other side, other publications refer that one of the many attributes or dimensions of Smart Cities is "Sustainability" [9][13][33][34], and that "*a general goal of Smart Cities is to improve sustainability with the help of technologies"* [30].

The vision of Smart Cities according to the European Commission (EC) is beyond the use of ICT. It is seen as interactivity between different infrastructures with the main goal of providing benefits in all sectors. According to the EC [35] Smart Cities are *"Cities using technological solutions to improve the management and efficiency of the urban environment"*. The EC [35] refers to Smart City as *"a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business"*. It is also stated that *"a smart city goes beyond the use of information and communication technologies (ICT) for better resource use and fewer emissions. It means smarter urban transport networks, upgraded water supply and waste disposal facilities and more efficient ways to light and heat buildings. It also means a more interactive and responsive city administration, safer public spaces and meeting the needs of an aging population*" [35].

IEEE also has this broader understanding of the Smart City concept where technology is seen as an enabler for a better quality of life and to decrease environmental impacts [30]. IEEE Smart Cities Initiative refers that *"a Smart City brings together technology, government and society and includes but is not limited to the following elements: A smart economy, Smart energy, Smart mobility, A smart environment, Smart living, Smart governance"* [36].

The United Nations, on their "Smart Cities and infrastructure report" [37] also refer that there is no standardized commonly accepted definition for Smart City. In the report [37], it states, as a reference, the definition provided by the International Telecommunication Union (ITU) after analysis in 2014 about 100 different definitions, and presented at the ITU-T Y. 4900 recommendations [38]: *"an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, the efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects"*. Although this definition provided by ITU [38] is actually for "Smart Sustainable City", the United Nations use it as a reference when mentioning to the definition of Smart City, stating also that *"Governments and stakeholders need to work together to develop a common understanding of what Smart City means in their specific national and city-level contexts"* [37]. Nowadays, the United Nations refers to the wording "Sustainable Cities and Communities" as a means to *"make cities and human settlements inclusive, safe, resilient and sustainable"* [39].

3. Smart City Assessment

As referred by Sharifi [13] Smart City Assessment (SCA) *"is a nascent field with much potential for future development"*. There is limited research analyzing SCA tools that Sharifi [13] attributes to the fact that SCA is a relatively new field of research and practice. The evaluation of Smart City implementations should be seen as critical, in order to historically document their strengths and weaknesses, for the scope of future improvements and to inform interested stakeholders about the level achieved in different target goals. SCA tools can also be used to present city-rankings, revealing the best (and the worst)

places for certain activities, which is pointed out by literature to be a central instrument for assessing the attractiveness of urban regions [21][40][41]. The SCA and resulting rankings can thus be used by cities to improve their position in the competition with other regions. A highly reputed city ranking helps to improve the international image of a city and can, therefore, play a central role in its marketing strategy [21]. Giffinger [21] mentioned a detailed analysis and comparison of 10 German rankings. The city rankings referred to in (Giffinger et al., 2007), which have been published by the magazines focus, capital, impulse, and Bizz between 1994 and 2003, point out the following benefits for city rankings:

- City rankings draw public attention to major issues affecting the quality of life of the citizens and promote healthy competition;
- City rankings stimulate a broad discussion on regional development strategies;
- Regional actors are forced to make their decisions transparent and comprehensible;
- Positive changes are also registered outside the region;
- The results in detail may initiate the learning effects of local actors;
- On the other hand, the same report identifies the handicaps of city rankings;
- City rankings tend to neglect complex interrelations in regional development;
- The discussion is mainly focused on the bare rank;
- Long-term development strategies may be threatened;
- Existing stereotypes may be strengthened.

4. Conclusion

This work provided insights about the existing gaps in the available SCA tools. Future research needs to be carried out on the analyses of indicators sets that could be included in a SCA tool, capable of overcoming several of the existing identified gaps. Also, it will be useful for the evaluation that, as much as possible, several of these indicators could be automatically acquired using automated information systems like sensing and metering devices and other data collection platforms, namely smart energy meters, smart water meters, outdoor air quality stations, traffic monitors, and waste management platforms. The authors are researching the development of such a SCA tool that can create added value in relation to the existing ones, contributing to overcome some of the existing identified gaps. The SCA tool under development will not only provide an overall rating of Smart City implementations, with all the multiple benefits for different stakeholders, but also will be able to provide different size implementation comparisons, historical overview and evolution, and different ratings for the main involved stakeholders, using a multi-criteria/multidimensional analysis. The different ratings will not only establish an overall rating of the city, but also a rating reflecting the different stakeholder's points of view (i.e., city authorities, investors, researchers, citizens). This framework is believed to contribute significantly to the knowledge, evaluation, and empowerment of the stakeholders, increasing their willingness to actively contribute and participate in future implementations. Such an SCA tool can also be used in validation methodologies of both large- and small-scale pilot implementations, since it will consider the scale of the implementation.

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