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The Concept of Sustainability in Smart City Definitions

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Smart cities have emerged as a possible solution to sustainability problems deriving from rapid urbanization. They are considered imperative for a sustainable future. Despite their recent popularity, the literature reveals the lack of conceptual clarity around the term of smart city, due to the plethora of existing definitions. This comprehensive literature review has identified 43 smart city definitions assessed according to the dimensions of sustainability that they consider, environmental, economic or social, and the priority in which they accord the concept of sustainability. The study revealed the common and opposite characteristics of the definitions according to the sustainability dimensions they consider and discussed the limitations they present. Such limitations appear to be related to citizen accessibility, misrepresentation and the particularity of existing urban fabrics. Taking into account these issues, as well as the difference between the smart city vision and its actual implementation, a new updated definition is proposed. The findings of the present study contribute to knowledge and practice by aiding conceptual clarity and, in particular, by drawing attention to underlying assumptions about the role of sustainability in smart city development.

Keywords: sustainable city, smart city, urban sustainability, definition, social sustainability, environmental sustainability, quality of life

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INTRODUCTION

It is estimated that by 2050, 66% of the global population will be residing in cities, compared to ∼54% residing now (UNEP, 2018). This implies that 2.4 billion people will be potentially added to the global urban population. Consequently, this will inevitably result in a significant expansion of existing urban environments and lead to the need to create new ones. Cities use <2% of the earth's surface, yet consume more than 75% of the natural resources available globally. The United Nations Environment Programme (UNEP, 2018) estimates that the material consumption related to cities will augment to ∼90 billion tons by 2050 compared to 40 billion tons in 2010. Some of these resources are primary energy, raw materials, fossil fuel, water and food (UNEP, 2012).

As a result, cities are expected to experience challenges related to growth, performance, competitiveness and residents' livelihood (McKinsey & Company, 2013). Deterioration of liveability challenges related to waste management, scarce resources, air pollution and traffic congestion that cause human health concerns, as well as aging public infrastructure, are some of the problems generated by rapid urbanization (Washburn et al., 2009). In order to address these issues, the smart city concept has emerged as one of the possible solutions.

A smart city is a city that may aims to make itself "smarter," more sustainable, efficient, equitable, and liveable (NRDC, 2012). There are numerous definitions of smart city in the literature many of which are diverse in nature. Their diversity ranges from what elements a city needs to encompass to be deemed as smart, to what resources it needs to employ, what characteristics it needs to present and what are the smart city's goals, purpose, and scope. While the term is increasingly being used in a variety of sectors, this plethora of scopes within the smart city definitions has led to confusion amongst urban policymakers, working on establishing public policies to enable the transition to smarter cities (Albino et al., 2015). This transition is considered as essential by policymakers and is reflected in the establishment of the 11th UN Sustainable Development Goal (SDG), aiming on making cities inclusive, safe, resilient and sustainable (UN, 2018). The European Commission alone has assigned a budget of nearly one billion euros on smart city projects, for the period 2014–2020 (EIP-SCC, 2013). As smart cities are continually becoming more prominent, the confusion in their scope is becoming increasingly alarming and will have effects on the creation of public benefit and value. Thus, drawing from the correlation between the 11th SDG and smart cities, this paper addresses a significant gap in the literature related to what extend the scope of sustainability is addressed in smart city definitions, and what is its role. This study presents a comprehensive literature review of the role of sustainability in smart city definitions. The goal of this paper is to aid conceptual clarity by drawing attention to underlying assumptions about the pivotal role of sustainability in smart city development. This conceptual clarity is essential not only to the advancement of scholarship and practice but more importantly in the decision-making processes of public policymakers.

SUSTAINABILITY AS ONE OF THE STRATEGIC GOALS OF SMART CITIES

The steep growth in urban population and the subsequent increase in resource consumption will inevitably create numerous challenges for cities. This fact highlights the importance of shifting paradigms in the way cities work in terms of sustainability. For the purposes of the present study, it is important to establish a working definition of sustainability. Allen and Hoekstra (1993) highlight the importance of establishing the scale on which a system is being assessed in terms of sustainability. Achieving sustainability on a global scale requires different type of actions than on an urban scale. There is no single best-established definition in terms of sustainability in the urban scale nevertheless there is a commonly-used set of characteristics of urban sustainability. These include intergenerational equity, intra-generational equity (social, geographical, and governance equity), conservation of the natural environment, significant reduction of the use of non-renewable resources, economic vitality and diversity, autonomy in communities, citizen well-being, and gratification of fundamental human needs (Maclaren, 1996).

These characteristics incorporate the three dimensions of sustainability: the environmental, the economic and the social dimension (Lehtonen, 2004), where the environmental regards the ecological aspect and includes the conservation of the natural environment (flora and fauna) and natural resources and an energy production based economy. The social dimension includes equity, community autonomy, citizen well-being, and gratification of fundamental human needs, while the economic one consists of the economic vitality and diversity of urban areas. For the context of this research an urban environment can be sustainable when social equity, conservation of the natural environment and its resources, economic vitality and quality of life are achieved. Urban sustainability appears to be one of the prevailing themes in smart city literature, but to what extent is the concept embedded in the understanding of smart cities and how comprehensively is it addressed?

METHODOLOGY

This research aims to provide a comprehensive review of the role of sustainability in smart city definitions found in the literature. In order for this review to be representative of the status quo in the sector, the definitions presented have been retrieved from academic papers on the conceptualization of smart cities, from organizational and governmental reports, as well as from documents and reports produced by industrial actors. Each type of definition was retrieved following a different process.

The academic definitions were accumulated following a five step procedure: searching a database using keywords, selecting language, selecting sector, selecting the 50 highest cited papers and identifying original non-repeated definitions. The definitions were identified in papers that were searched through inserting relevant keywords in the Elsevier's Scopus database. These keywords were "smart city," "smart cities," and "definition" and they were selected to be occurring in the abstract. Solely English language papers were selected. As the research field of smart city is multidisciplinary and diffused, the following subject areas were selected: social sciences, environmental science, energy and business management, and accounting. Computer science, engineering and mathematics related papers were not consulted, in order to keep the focus on the conceptual part of the subject in question and not on the technological side of smart city. This is due to the fact that smart city literature appears most frequently focused on the realization of technological solutions (Letaifa, 2015), such as cloud technology, Internet of Things (IoT), 5G and industry 4.0, rather than providing a critical understanding of the concept and its implications. The first 50 most highly cited papers were selected and examined. The examination process identified that the majority of these papers repeat and reuse the same definitions, either singularly or combined between each other in various ways. For this review, the definitions that were selected from the papers were original, non-repetitive and not based on combinations of other authors'.

Secondly, a list of smart city organizations was retrieved through the partnership list of the United Smart Cities organization, coordinated by the Organization for International Economic Relations (OiER) and the United Nations Economic Commission for Europe (UNECE). Not all organizations had produced documents and reports were smart city is clearly defined. The documents produced by these organizations that were found, were assessed, and as per above, original definitions were retrieved. Finally, the list of industrial players was composed through a combination of the United Smart Cities organization industry partners database and the Future

Cities Catapult industry database, now called Connected Places Catapult, the latter being the leading smart cities organization in the UK, originally created by the Department for Business, Innovation, and Skills (BIS). For the majority of the industrial players, no definitions could be found in their open access resources, while many of the definitions present, were repetitive/non-original. Reports produced by industrial partners were reviewed and original definitions were retrieved. Definitions that appeared repetitive were discarded in order to generate a streamlined/focused dataset.

The analytic method evaluated the definitions retrieved according to:

- Whether sustainability, defined in this context as the coexistence of social equity, conservation of the natural environment, economic vitality, and quality of life in the urban environment, is considered as one of the smart city goals;
- Which dimensions of sustainability, environmental, social, or economic, are taken into account;
- How sustainability goals are prioritized. Prioritization was assessed according to whether sustainability appeared as a primary, secondary, or tertiary goal, where primary was indicated as of fundamental importance, secondary as important but not fundamental goal and tertiary a goal of less importance compared to the other two categories. Although subjectively classified, the three level of priority offer an indication on the centrality of sustainability in smart cities definitions.

FINDINGS

This study identified 43 definitions in the literature, the majority of which come from academia (16 definitions), while 14 were found in organizational/governmental reports and 13 in documents from the industry. The next section presents an overview of the definitions, followed by a more detailed examination of the variances in sustainability oriented and non-sustainability oriented definitions. Subsequently, the dimensions of sustainability, namely the environmental, economic, and social dimension, as well as the prioritization of sustainability as a smart city goal in the definitions, are presented.

Overview of Smart City Definitions

Numerous definitions encompassed all three dimensions of sustainability namely, the environmental, economic and societal, while others examined only one or a combination of two dimensions (**Table 1**). Smart city definitions are heterogeneous in nature (Ponting, 2013), as there appears to be neither a predetermined template, nor a one-size fits-all definition of what the term smart city encompasses (O'Grady and O'Hare, 2012). As such, definitions tackle different perspectives of smart city development ranging from the adoption of Information and Communication Technology (ICT), user communication, e-governance and equitable development to education and sustainability. In addition to variations in content, sustainability-oriented definitions present a discrepancy in the prioritization of sustainability as a smart city goal. In many of the definitions presented, sustainability is regarded as one of the primary goals of smart city, along with liveability. Respectively, approximately one third of the definitions presented, feature sustainability as one of the secondary goals in smart cities along with liveability, efficient use of resources and governance. Few definitions presented sustainability as a tertiary goal, diminishing its importance in the smart city agenda. The primary goal in tertiary definitions is the quality of life and governance.

Smart cities are described as resilient and inclusive cities built collaboratively, that use different types of technology and data in order to achieve a better quality of life for all their residents (Evergreen, 2018). They can be viewed as cities performing well on six characteristics: environment, economy, mobility, people, living and governance (Giffinger and Pichler-Milanović, 2007). They derive from knowledge-intensive creative strategies that have as a goal the improvement of the socio-economic, ecological, logistic and competitive performance of cities and rely on a mixture of human, infrastructural, social and entrepreneurial capital (Kourtit and Nijkamp, 2012). These investments in human, infrastructural (transport and ICT) and social capital promote sustainable economic growth and a good quality of life, via participatory governance and by intelligently managing natural resources (Caragliu et al., 2011).

Definitions that did not include sustainability as one of the smart city strategic goals, viewed it as a city that utilizes ICT to create more interactive and efficient components and utilities of critical infrastructure (Azkuna, 2012). These components were suggested to be administration, education, healthcare, public safety, real estate, transportation, and utilities (Bélissent, 2010). When describing the vision for Smart London, the London Assembly (2013) regarded such components as systems integrated through different technologies. It focused on the linkage between local labor markets to financial markets and from the local government to education, healthcare, transportation, and utilities. Smart cities will use communications and sensor capabilities embroidered into the infrastructure of the city in order to optimize electrical, transportation-related and other logistical everyday operations, with the goal of improving quality of life (Chen, 2010). Such technologies provide an interaction space between citizens, authorities, businesses, and other actors, to become actively engaged in the design and planning processes (Batty et al., 2012).

While the definitions above derived from academic literature and governmental papers, similar themes can be observed in definitions deriving from industrial actors. Smart cities adopt scalable solutions that utilize ICT to boost efficiency, decrease costs and improve quality of life (Falconer and Mitchell, 2012). IBM (2009) considers that a city can become smart by optimally using all the available interconnected information to comprehend and regulate its operations and optimize the utilization of available resources. Accordingly, others supported that a smart city can be built by integrating platforms, terminals and data, through policy, technology, and capital, in an efficient way (Fiberhome Technologies Group, 2018). Technology is used as a means to better all aspects of city operations and improve the services offered to citizens. Data are collected and used to

TABLE 1 | The definitions retrieved by the literature and cataloged according to whether they are sustainability oriented and if yes, which dimension (environmental, economic, or social) is present in the definition and how high of a priority it appears to be.

Author	Keywords	Environmental	Economic	Social	Priority
SUSTAINABILITY ORIENTED DEFINITIONS					
Academic Definitions					
Bakici et al. (2010)	High-tech, connections, ICT, sustainable, greener city, competitive, innovative	•	•	•	Primary
Barrionuevo et al. (2012)	Technology, resources, integrated, habitable, sustainable			•	Secondary
Caragliu et al. (2011)	Human and social capital, ICT, Infrastructure, sustainable economic growth, quality of life, participatory governance	•	•	•	Primary
Lazaroiu and Roscia (2012)	Technology, interconnected, sustainable, comfortable, attractive and secure			•	Secondary
Giffinger and Pichler-Milanović (2007)	Economy, mobility, environment, people, living, governance	•	•	•	Primary
Kourtit and Nijkamp (2012)	Knowledge-intensive creative strategies, socio-economic, ecological, logistic competitive, human capital infrastructural, social and entrepreneurial capital	•	•	•	Primary
Kourtit et al. (2012)	Productivity, education, knowledge intensive jobs, creative, sustainability oriented			•	Tertiary
Nam and Pardo (2011)	Information, infrastructure, efficiency, mobility, decision making	•		•	Primary
Schaffers et al. (2012)	ICT, social and environmental capital, competitiveness	•		•	Secondary
Thuzar (2011)	Sustainable urban development policies, equity, sustainable economic development, human social capital, natural resources	•	•	•	Secondary
Toppeta (2010)	ICT, governance, sustainability, liveability			•	Primary
Zygiaris (2013)	Innovative socio-technical and socio-economic growth, green, interconnected, intelligent, knowledgeable, innovating, interactive	•	•	•	Secondary
Industrial Definitions					
Alcatel-Lucent (2012)	ICTs, competitiveness, environmental sustainability, liveability	•	•	•	Secondary
Bosch (2019)	Technology, quality of life, traffic, intelligent homes and energy efficient buildings	•		•	Tertiary
Hitachi (2012)	Environment, safe, quality of life	•		•	Primary
McKinsey (2018)	Digital intelligence, information, tools, services, businesses	•		•	Secondary
Microsoft (2018)	ICT, services, public utilities, safer and healthier city	•		•	Secondary
Aoun (2013)	Efficient, liveable, sustainable	•		•	Primary
Siemens (2017)	Resilience, social and human aspect, technology, services	•	•	•	Primary
Telefonica (2016)	Improving public services, quality of life, governance, sustainability			•	Tertiary
Institutional Definitions					
BIS (2013)	Liveable, resilient, engaging, hard infrastructure, social capital		•	•	Tertiary
BSI (2014)	Integrative, physical, digital and human systems, sustainable, inclusive			•	Secondary
EIP-SCC (2013)	Energy, materials, services and capital, sustainable economic development, resilience, quality of life	•	•	•	Primary
EIP-SCC (2013)	Technologies, environmental impact, better lives, governance	•		•	Primary
European Commission (2019)	Networks, services, ICT, resource use, emissions	•		•	Primary
Evergreen (2018)	Resilience, inclusivity, collaboration, data, quality of life			•	Primary
ICLEI (2017)	Operations, sustainable, resilient, physical and social capital	•	•	•	Primary
IDA (2006)	ICT, real-time analysis, sustainable economic development.		•		Primary
International Telecommunication Union (2016)	ICT, quality of life, city services, competitiveness	•	•	•	Primary
ISO 37122 (2019)	Collaboration, data, technology, quality of life, natural environment	•	•	•	Primary
NRDC (2012)	Efficient, sustainable, equitable, liveable	•		•	Primary
NON-SUSTAINABILITY ORIENTED DEFINITIONS					
Academic Definitions					
Batty et al. (2012)	ICT, infrastructures, coordinated, equitable, engaging				
Bélissent (2010)	ICT, infrastructure, interactivity, efficiency				
Chen (2010)	Communications and sensor capabilities, infrastructures, optimization, quality of life				

(Continued)

TABLE 1 | Continued

McFarlane and Söderström (2017)	Data, technology, locality
Industrial Definitions	
ARUP (2010)	Engaged citizens, efficient, interactive, engaging, adaptive and flexible city
Falconer and Mitchell (2012)	ICT, increase efficiencies, reduce costs, quality of life
Deloitte (2018)	Technology, city operations, data, networks, decision-making
Fiberhome Technologies Group (2018)	Data integration, policy, technology, process, capital
IBM (2009)	Interconnected information, operations, optimization of resources
Institutional Definitions	
Azkuna (2012)	ICT, infrastructure, efficient, citizen awareness
Future Cities Catapult (2017)	Marketing, global tech industry, digital transformation
London Assembly (2013)	Systems, collaboration, technology

The dot (•) means that the definition includes that dimension. Table created by the authors.

inform decision-making and at the same time create networks of partnerships between governments, businesses, non-profits, community groups, universities, and hospitals (Deloitte, 2018). From a different point of view, ARUP (2010), viewed the smart city as a city with clear and transparent structure of its urban systems, which are simple, responsive and adaptable with the use of technology and design methods. In this city, citizens are encouraged to interconnect with their wider ecosystem and collectively engage with it (ibid).

Variously, some non-sustainability oriented definitions described smart cities more critically, exploring their origin and promises. More particularly, smart urbanism, which gave birth to smart cities, has been described as "a loosely connected set of confluences between data, digital technologies, and urban sites and processes," while the "promise continually sold is of the digitally enabled data-driven, continually sensed, responsive and integrated urban environment" (McFarlane and Söderström, 2017, p. 314). Smart city itself was also described as a concept that became popular in early 2010 on how recent technological advancements and data can enable more efficient city management but was established in "public consciousness as a marketing concept from global technology companies that saw an opportunity to sell digital transformation and new technology into big city systems" (Future Cities Catapult, 2017, p. 4).

In summary, while sustainability-oriented definitions appeared to focus on the performance of the environment, economy, mobility, people, quality of life and governance, non-sustainability-oriented definitions were particularly interested in the efficiency of transportation, education and administration. Despite the common characteristics, sustainability-related smart city definitions presented, they also demonstrated a number of variations. Different smart city definitions may include different dimensions of sustainability as their goal. Furthermore, the prioritization of sustainability as a strategic smart city aim appeared to vary between definitions.

Sustainability Oriented Smart City Definitions

Sustainability oriented smart city definitions from the selected sources, were analyzed according to the dimensions of sustainability they encompass, namely the environmental, the social and the economic dimension. This categorization allowed for thematic patterns to be identified. Firstly, definitions that consider all three dimensions are discussed. For these, the term "holistic approaches" is used here. They view the "smartness" of a city as a "certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth" (Zygiaris, 2013, p. 218). Such perspective demonstrated the perception of a smart city as green, interconnected, intelligent, innovating and knowledgeable; terms which themselves have been the subject of a number of literature reviews. This "smartness" is embedded into the city operations and is based on the analysis, monitoring and optimization of urban, physical (energy, water, waste, transportation and others) and social (equity, governance, citizen participation) systems, through transparent and inclusive communication structures (ICLEI, 2017). Accordingly, Siemens (2017) considered that the term "smart" does not only affect the technological aspect of the operations, but has a social and human aspect as well. The addition of sensors and updating existing urban infrastructure will positively affect the efficiency and capacity of the delivery of services, economic opportunity and quality of life for citizens. Similarly, smart cities can be regarded as systems of humans, utilizing flows of energy, materials, services, and capital to achieve sustainable economic development, resilience, and high life quality (EIP-SCC, 2013). The challenges smart cities respond to are related to climate change, rapid population growth, and political and economic instability. They do so through collaborative leadership and cross-disciplinary, city-wide collaboration and the use of data and technology, with the goal of providing better services for their citizens, but without causing unfair disadvantage to other citizens or further degrading the natural environment (ISO 37122, 2019). While the end goal is to improve the quality of life, efficiency of city operations and competitiveness, smart cities need to ensure that they meet the needs of present and future generations from all aspects: economic, social, environmental and cultural (International Telecommunication Union, 2016). In order for smart cities to achieve these goals, equitable, participatory, sustainable urban development policies will need to be developed (Thuzar, 2011).

Predominantly, environmentally oriented definitions, focused on the impact that digital technologies will have on particular urban services. Such technologies can be used to improve the use of resources and decrease emissions. This can lead to not only smarter transport infrastructure, improved water supply and waste disposal systems and more efficient building thermal control, but also improved city administration services, safer public spaces, and better response to the needs of aging population (European Commission, 2019). Numerous industrial actors, with operations predominantly in the IT sector, provided definitions similar to the one from the European Commission. Microsoft (2018) considered smart city as one that uses ICT to improve the provision of citizen services like energy, water, public safety and transportation increasing the health, sustainability, resilience and safety of cities. Bosch (2019) provided an analogous definition supporting the idea that the use of various technologies can improve the citizen's general quality of life, through saving time, using new mobility methods and breathing cleaner air and lead to decreased traffic, intelligent homes, and energy-efficient use of buildings. Nevertheless, citizens' quality of life and a more comfortable, safe, and convenient lifestyle, should be in harmony with the environment, and smart cities should aim in enabling a well-balanced relationship between people and the Earth (Hitachi, 2012), as the efficient, liveable, and sustainable elements should go hand-in-hand (Aoun, 2013).

Interestingly, all sustainability oriented smart city definitions identified included a strong presence of the social dimension as well. When the concept of smart city was introduced, it was regarded as a strategic tool to underline the increasing importance of ICT and social and environmental capital in sculpting the competitiveness of modern cities (Schaffers et al., 2012). Consequently, smart city definitions that encompass the environmental dimension of sustainability frequently include the social dimension. Schaffers et al. (2012) argued that this is due to the distinctive attributes that social and environmental capital can offer to smart cities compared to the "more technology-laden counterparts," frequently mentioned in the literature as digital or intelligent cities. Thus, the distinction between digital or intelligent cities and smart cities appears to be the prevalence of the human element in the latter.

Indeed, numerous sources in the literature, view sustainability in smart city as a predominantly social scope. The British Standards Institute (BSI), the national standards body of the United Kingdom, supported that a smart city includes the efficient integration of physical, digital and human systems in the built infrastructure in order to create a sustainable, prosperous and inclusive future for its inhabitants (BSI, 2014). This emphasis on the habitability and inclusivity of the urban environments particularly underlines the social nature of smart cities. Via the use of digital intelligence, tools can be designed that save lives, prevent crime, and reduce the disease burden. These can save time, reduce waste, and even help boost social connectedness (McKinsey, 2018). In other words, smart cities strive to improve city services and urban management for the citizens, by creating a socially advanced environment. The ultimate goal of these processes is to improve the sustainability and liveability of the city (Toppeta, 2010). Through these definitions, it can be observed that the combination of human capital with technology can have an effect on urban services, city services, local actor interaction, and quality of life, thus improving the social aspect of urban environments.

The identified literature included few definitions that focus solely on the economic aspect of sustainable smart cities. Similarly, to the environmentally oriented definitions, the economic oriented ones considered smart cities as cities that combine hard infrastructure with social capital, community institutions and technologies, but with an alternative purpose: that of boosting sustainable economic development and creating an attractive business environment (BIS, 2013). According to this approach, economic competitiveness along with environmental sustainability and general liveability become increasingly driven by ICT (Alcatel-Lucent, 2012). In the case of Singapore, the smart city has been defined as a local entity that holistically employs ICT and real-time analysis to promote sustainable economic development (IDA, 2006). Barcelona considered smart city as a sustainable, greener, highly technological city with competitive and innovative commerce, and an enhanced quality of life that creates connections between people, information and urban elements, through the use of new technologies (Bakici et al., 2010). This approach is a less theoretical and more practical one, where the need for sustainable development is recognized along with the need of the city to grow and flourish economically, through the combination of both hard and soft elements. However, these resources do not make clear if economic growth and enhanced quality of life are causally related, with economic improvement leading to better quality of life, or if these two goals should be independently pursued.

DISCUSSION

Some consistently appearing themes were identified from the three types of literature examined. These are: the relatively anthropocentric focus of sustainability-oriented approaches, the prevalence of result-focused definitions and the role of technology as a facilitator. Sustainability oriented approaches are related to the use of soft and hard capital, where soft capital is considered as human capital and societal structures and hard capital as the city infrastructure and material resources, combined through diverse technologies, with the purpose of enhancing environmental aspects of the city, boosting the economy and ensuring a high quality of life. In contrast, non-sustainability related definitions particularly highlighted the importance of ICT in order to optimize the performance of the city and the use of resources, while the ultimate purpose of enhancing the quality of life remains still a high priority.

The variation in themes between the two types of definitions demonstrated how the first type combines soft capital (the human and societal element), to hard capital (city infrastructure), while the second one focuses on the efficient utilization of resources through the use of ICT, thus underpinning the importance of hard elements. This can be specifically observed in definitions provided by technologically related industrial actors (IBM, 2009; Falconer and Mitchell, 2012; Siemens, 2017; Fiberhome

Technologies Group, 2018). In contrasting, other actors in the ICT industry, such as Hitachi (2012), Aoun (2013), and Microsoft (2018), provided more sustainability oriented, holistic definitions. This may be due to the fact that these firms are not solely ICT based but have a diversified portfolio that ranges from power and automotive systems to social infrastructure. In a similar alignment of sector and definition, ARUP, a company related to the built environment, defined smart city as an urban system with structures focused on citizens and their neighborhoods, thus underlining the urban aspect.

Additionally, it can be observed that sustainability oriented definitions appeared more results based, while non-sustainability oriented definitions more process based. Most sustainability oriented definitions highlighted the results that smart cities aim to achieve answering to "why a city should be smart," while the non-sustainability-oriented definitions appeared to answer to "how these results can be achieved," through expanding on the integration of different kinds of resources, such as human and infrastructure capital, in order to achieve the smart city goals. This is furthermore noticeable in the role of technology, which in the first approach came across as a facilitator to an end-result, while in the non-sustainability-oriented approach technology took a more prominent role.

Holistic approaches took into consideration all sustainability dimensions, the environmental, the social and the economic, and presented a rather balanced point of view on what a smart city should be. Environmentally oriented definitions, which included the social dimension as well, supported the cause of reduction of the environmental impact of urbanism, the enhancement of life quality and the efficient use of resources as the smart city goals. These may be achieved through the use of technology in almost all definitions. This approach emphasized mitigating the impact of cities on the environment and rarely takes into account the economic growth or development of the city. In doing so, such definitions sidestepped growing argument on the incompatibility between continuous economic growth and environmental sustainability, and the need for a paradigm shift to de-growth.

Similarly, social sustainability-oriented definitions demonstrated how smart cities integrate technology with governance to improve the sustainability and liveability of the city. In contrast to socially oriented definitions, those focused on the economic dimension of sustainability proposed the combination of hard infrastructure and soft capital with the purpose of creating competitive cities and boosting sustainable economic development.

A prevalence of socially related elements may be observed in smart city sustainability oriented definitions. This is contrary to the urban sustainability literature where frequently the societal factor is overlooked or shadowed by the ecological aspect (Lehtonen, 2004). This phenomenon is also extended to the urban sustainability assessment literature (Berardi, 2013). Nevertheless, the human nature of urbanization and the social issues that rapid urban growth has caused, such as social inequality (Kim and Han, 2012), social deprivation, community disruption, public safety, and health decrease (Bibri and Krogstie, 2017), have underlined the importance of the social aspect of smart cities and appear to have had a significant impact on the way in which scholars, organizations and industries define the term. Even though the definitions underpinned the importance of the social aspect, the current implementation of the smart city model paints a different story, where technology comes first and resolution to social problems comes second (Hollands, 2015; McFarlane and Söderström, 2017). While industrial actors are developing ICT solutions that cater to a variety of clients, such as governmental agencies, other enterprises and civic society, it is currently unclear whether these technologies facilitate the scope of improvement of the "general" quality of life of all citizens, or whether they benefit a specific "elitist" part of society that is digitally skilled and can financially afford these solutions, while excluding another one. This part of society can be a local council of a low-income borough, a state school with limited resources, an immigrant camp, an elder or a low-income young citizen. These smart city solutions may improve the quality of life of some citizens, while at the same time may marginalize and create a deeper gap between those who have access to "smart" and those who have not (Datta, 2014). This may lead to the misrepresentation of specific communities that have limited or no digital footprint, as happened with Hurricane Sandy, which through social media falsely appeared to be centered on Manhattan, due to higher access and engagement to social media from that location (Crawford, 2013) and consequently led to false assumptions and adverse actions from leadership. Social exclusion issues go beyond representation and access to technology, to distortion of the "reality of a city" and the particular characteristics of a locality, such as the history, concerns, knowledge and trajectories of the existing urban community (McFarlane and Söderström, 2017). In other words, while existing smart city definitions appeared to highlight the importance of the social aspect and quality of life, many of them did so by excluding a part of the population with limited access to technology and by stripping off the particularities of the existing urban fabric, in a way that may be considered as parallel to a process of gentrification.

In contrast with the social dimension, a low number of definitions that took economic sustainability into account can be observed. This is contrary to the common connection between social and economic sustainability, frequently referred to as "socio-economic," indicating the strong connection between these two elements in the wider literature. This tendency of the definitions to disassociate from the economic aspect can additionally be observed in the way in which particularly industrial definitions downplayed the importance of economic sustainability in the implementation of the smart city vision. This is opposite to the reality. The smart city model is being promoted and supported with significant investment of resources by numerous industrial actors (Söderström et al., 2014). It is a highly competitive market, where there is an evident risk of prevalence of stand-alone profit-making agendas (Sadowski, 2016), that may undermine economic development through their isolated ICT branding exercises (Allam and Newman, 2018). This risk becomes more and more imminent when examining the financial growth of the smart city market. The market is expected to have a 20% growth rate per year, from over \$300 bn in 2015 to over \$750 bn in 2020. Thus, it is evident why technology companies view smart cities as an opportunity to promote digital transformation (Future Cities Catapult, 2017).

It is apparent that the diverse sustainability oriented definitions of smart city did not view the goal of sustainability equally. Most definitions that took a holistic approach appear to view sustainability as one of the primary city goals. Interestingly, this is not the case for socially oriented definitions which focused more on quality of life and development or efficient use of the human capital, thus view sustainability as a desirable attribute, but has secondary or tertiary priority. This raises questions as to what trade-offs predominantly socially oriented smart cities are willing to make in order to achieve quality of life over the preservation of the environment, as well as what the cost of this trade off will be. Additional concerns are raised by the fact that no definition provides an explanation of what is meant by quality of life and what it incorporates. Undoubtedly, quality of life has different meanings for different parts of the world, as access to food, clean water and medicine as well as equity and equal opportunities are still an on-going problem in numerous parts of the globe.

Regardless of the number of sustainability-driven smart city definitions and its apparent high priority as a goal, some authors pose questions regarding to the true impacts of smart city on ecological sustainability. One of the arising issues is the potential psychological disconnection of citizens from the environment and disruption of their relationship with nature due to overexposure to technology (De Jong et al., 2015). Additionally, some authors disputed the net contribution of smart cities to sustainability (Gargiulo Morelli et al., 2013; Viitanen and Kingston, 2014). These are supported by the findings of De De Jong et al.'s (2015) network analysis of smart city concepts, which indicates a distance between the sustainable and the smart city. Whether these concerns are valid or not largely depends on the way in which the smart city model is or will be embedded in the urban system, and the strategies and main goals that the authorities will set for each city, as well as the resources that will be used in order to achieve it.

After analyzing the existing smart city definitions, it can be observed that most of the definitions, as currently present in the literature, described a utopian urban environment that frequently disregards issues of the societal and environmental urban reality. This indicates the need for a re-adjusted definition that takes into consideration the issues raised above and most specifically: excluding groups of citizens, stripping off the particularities of the existing urban fabric by equalizing all localities, creating confusion between the environmental trade-offs needed to achieve an undefined quality of life and regarding technology as the central solution and not as a facilitator.

Taking into account these points, as well as drawing on wider literature the following definition is proposed: Smart city is a concept of urban transformation that should aim to achieve a more environmentally sustainable city with a higher quality of life, that offers opportunities for economic growth for all of its citizens, but with respect to the particularities of each locality and its existing inhabitants. This transformation is currently enabled by various types of technologies, typically provided by global industrial partners, that are embedded into the city's infrastructure system, transforming the existing provision of services by adding layers of interconnectedness.

CONCLUSIONS

This comprehensive literature review identified a number of emerging themes in smart city definitions. Sustainability oriented definitions often focus on the combination of soft capital, such as human and social capital, and hard capital, a city's physical infrastructure, in order to deliver a sustainable, liveable and efficient city. On the other hand, non-sustainability-oriented definitions usually highlighted the importance of ICT utilization to efficiently combine resources that will make the city more interconnected, intelligent and liveable.

Holistic approaches covered all dimensions of sustainability, the environmental, the social and the economic one, and presented a balanced point of view on what a smart city should be. Most environmental and social oriented definitions focus on how smart cities integrate technology with governance to improve the quality of life and reduce the environmental impact of urbanism. Conversely, the few economic oriented definitions proposed the combination of hard infrastructure and soft capital with the purpose of creating competitive cities and boosting sustainable economic development. A tendency of the definitions to downplay the importance of economic sustainability in the implementation of the smart city vision can be observed. This is opposite to the current implementation plans and the phenomenal growth rate of the smart city market.

Overall, interestingly in contrast with most sustainability related literature, the social dimension of sustainability appeared to be the prevailing one in smart city definitions, even though many of them appeared to exclude a part of the population with limited access to technology and disregard the particularities of the existing urban fabric, in a way that may appear similar to the process of gentrification. Additionally, throughout the definitions it was not clear if economic growth and enhanced quality of life are causally related, or whether they present competing agendas.

As a response to the points of interest identified and analyzed based on the existing literature, a new definition is proposed above. This definition is adjusted to address some of the most significant issues raised above and presents the key points that the smart city vision should consider, with a focus on holistic sustainability, inclusiveness and respect to localities and their inhabitants.

Further research on the contribution of smart cities to achieving sustainable development is essential. The exclusion of smart city definitions, that derive from papers on technological solutions from the fields of computer science, engineering and mathematics, is a limitation of this study. Future papers may address this, by including definitions from all fields. As this research indicated, one of the main goals of smart city initiatives is the improvement of quality of life, yet no definition explained what this means and at what cost this improvement will come for society and the environment. Thus, future attempts to define smart city should take the cause-effect relationship of improvement of quality of life through the use of modern technology into consideration and truly reflect on whether all dimensions of sustainability are equally represented.

AUTHOR'S NOTE

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AUTHOR CONTRIBUTIONS

AT and NM have both contributed to the conception and design of the study. AT composed the drafts of the manuscript, under the guidance of NM, who revised them multiple times. Both authors contributed to the manuscript revision, read, and approved the submitted version.

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