The Impacts of the Fourth Industrial Revolution on Smart Sustainable Cities

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Abstract

Studies on Sustainable Cities first appeared as cities are presented with new challenges and need to efficiently manage key resources, considering economic, social and environmental issues; while Smart Cities have emerged promoting the use of technology to improve quality of life and services in cities. A new concept of Smart Sustainable Cities has emerged using the Fourth Industrial Revolution and its technologies as tools to address challenges and boost the implementation of sustainable development. These city models represent a new way of optimizing resources and services, delivering more efficiency, satisfaction and quality of life for people, having the potential to remedy environmental problems and improve economic aspects. This article aims to analyze the impacts of the Fourth Industrial Revolution on the implementation of Smart Sustainable Cities. For this purpose, a data mining was done to analyze the terms that had higher incidence in literature in order to classify them by relevance and identify their interdependencies in the concepts of Sustainable Cities and Smart Cities. Considering that the Fourth Industrial Revolution is new and is still underway, this article contributes to a growing discussion in all spheres of society and aims to guide innovation in literature and policy-making.

Keywords: Smart Cities; Sustainable Cities; Smart Sustainable Cities; Fourth Industrial Revolution; Sustainable Development.

Resumo
Estudos em Cidades Sustentáveis surgiram ao passo em que as cidades precisavam lidar com novos desafios e a necessidade de manejá-los de maneira eficiente considerando as questões econômicas, sociais e ambientais; enquanto Cidades Inteligentes emergiram promovendo a utilização de tecnologia para melhorar a qualidade de vida e a qualidade dos serviços entregues nas cidades. Um novo conceito de Cidades Sustentáveis Inteligentes surgiu apoiada pela Quarta Revolução Industrial e suas tecnologias como ferramentas para enfrentar os desafios e impulsionar a implementação do desenvolvimento sustentável. Esses modelos urbanos representam uma nova maneira de otimizar recursos e serviços, proporcionando mais eficiência, satisfação e qualidade de vida às pessoas, com potencial para sanar problemas ambientais e melhorar os aspectos econômicos. Este artigo tem como objetivo analisar os impactos da Quarta Revolução Industrial na implementação das Cidades Sustentáveis Inteligentes. Para tanto, foi realizada uma mineração de dados para analisar os termos que tiveram maior incidência na literatura, a fim de classificá-los por relevância e identificar suas interdependências nos conceitos de Cidades Sustentáveis e Cidades Inteligentes. Considerando que a Quarta Revolução Industrial é nova e ainda está em andamento, este artigo contribui para a crescente discussão em todas as esferas da sociedade e visa orientar a inovação na literatura e na formulação de políticas.

**Keywords:** Cidades Inteligentes; Cidades Sustentáveis; Cidades Sustentáveis Inteligentes; Quarta Revolução Industrial; Desenvolvimento Sustentável

1. **Introduction**

Cities, by concentrating a large part of human activity, play an important role in social, environmental and economic spheres (MORI and CHRISTODOULOU, 2012). However, urbanization, added to unsustainable practices, generates negative impacts on the environment (YIGITCANLAR et al., 2018) not only at the local level, but with large-scale consequences called ‘ecological footprints’ beyond their immediate vicinity (WORLD ECONOMIC FORUM, 2018). According to UN data, 55% of the world's population lives in urban areas today, a proportion that is expected to increase to 68% by 2050 (UN, 2018). Cities continue to attract an increasing share of the people in search of a job and an improved quality of life (EUROSTAT, 2018). Therefore, in view of this inevitable growth of cities, it is estimated that their environmental impact tends to worsen (NEWMAN, 2006).

Large-scale accelerated population growth in the Earth and the increasing number of people living in cities drive the rate of global environmental change, such as greenhouse-gas-induced global warming, deforestation, desertification and loss of biodiversity (GRIMMOND, 2007). Moreover, they cause other types of problems that threaten the social and economic
sustainability of cities, such as unemployment, inadequate house, poor urban infrastructure, traffic congestion, educational challenges, health issues and energy shortages among others, leading cities to a vulnerability situation. (KUMAR; SINGH; GUPTA, 2018; UN Environment, 2018).

It becomes necessary to develop alternatives and more intelligent ways to revert, or at least reduce, these problems and deal with new challenges in this scenario where smart cities emerge (ZAWIESKA; PIERIEGUD 2018). In this context, Balakrishna (2012) states that the use of new innovations arising such as digital technology as a catalyst for the transformation of the urban environment points to an auspicious horizon, promising to deliver more efficiency and raise the population's quality of life from the adoption of smart services, systems and solutions (BROCK et al., 2019).

The current development of Industry 4.0 impacts profoundly in the manufacturing industry, once it motivates the creation of networks between environmental, social and economic aspects and the promotion of vertical integration (STOCK; SELIGER, 2016). It was first mention in 2011 as the use of high technology in order to achieve Germany economic goals (LU, 2017). Since then, the Fourth Industrial Revolution is seen as a way to get more rapid and efficient use of available resources in urban areas, adopting the following technology trends as bases: Big data and analytics; Autonomous Robots; Simulation; System Integration; Industrial Internet of Things; Cyber Security and Cyber Physical Systems; The Cloud; Additive Manufacturing; and Augmented Reality (RÜßMANN et al., 2015).

Technological innovations are commonly associated with the degradation of the environment, since population growth started, in 1960, caused several urban problems worldwide (NEWMAN, 2006). Consequently, Smart Cities and Sustainable Cities concepts emerge as proposals for a solution to problems caused and located in cities (OCHOA et al., 2018). In this context, Smart Sustainable Cities arise as a combination of several aspects as much relevant as economic growth, such as environmental and social issues smartness (ANAND; NAVÍO-MARCO, 2018).

This article aims to present Smart Cities, Sustainable Cities, Industry 4.0 and Smart Sustainable Cities based on several authors, comparing them and the relevance in literature by
the use of word clouds. From this, the study analyses the impacts of the fourth industrial revolution innovations in the social, economic and environmental spheres and its application in the urban context such as more rapid innovations, employment generation, better use of urban resources and longer products life cycle, contributing to the development of Smart Sustainable Cities.

2. Methodology

The analysis of the impacts of the Fourth Industrial Revolution in the implementation of Smart Sustainable Cities was conducted with a literature review with the following keywords: Sustainable Cities, Smart Cities, Smart Sustainable Cities, Fourth Industrial Revolution and Sustainable Development. The research was conducted in the databases Science Direct, Web of Science and Scopus. The choice of databases was due to their relevance. After the research, the 20 most cited articles and the 20 most relevant articles of each search in all the databases were select for the analysis of titles and abstracts. After that, 27 articles were selected for complete analysis and composition of the research portfolio. The results of each phase of the research are available in table 1.

<table>
<thead>
<tr>
<th>Table 1 - Keywords on Smart Sustainable Cities</th>
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<tbody>
<tr>
<td><strong>Keywords</strong></td>
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<tr>
<td>Sustainable Cities</td>
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<td>Smart Cities</td>
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<tr>
<td>Smart Sustainable Cities</td>
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<tr>
<td>Fourth Industrial Revolution</td>
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<tr>
<td>Total number of articles selected after reading titles and abstracts</td>
</tr>
<tr>
<td>Articles selected for analysis</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Source: Elaborated by the authors, 2019
After selecting articles as shown in Table 1, a data mining about the articles that present the main concept of Smart Cities and Sustainable Cities was conducted, corresponding to the second phase of the research. Those articles were organised and submitted to the Collocations Extraction process (CECI et al., 2012) in order to identify the terms that presented the highest frequency and their relations, with the aim of showing how international scientists have addressed issues about Sustainable Cities and Smart Cities. The following sections presented what the scientific literature presents about Sustainable Cities, Smart Cities, Sustainable and Intelligent Cities, Fourth Industrial Revolution, and the impacts of the Fourth Industrial Revolution on the deployment of Smart Sustainable Cities.

3. Smart Cities

Smart city it is not a strictly defined concept (SOLANAS et al., 2014), but is a term commonly used to refer to the convergence of technology and city (YIGITCANLAR et al., 2018). Although it is often mistaken with other similar but more specific terms — such as intelligent cities, information cities and virtual cities — smart cities aim to encompass all this and the main component that was missing: people (ALBINO, BERARDI and DANGELICO, 2015; BATTY, 2013). In other words, smart cities are at the interface between social and technological dimensions (ANAND; NAVÍO-MARCO, 2018), aiming to improve the quality of life for inhabitants (CHEN, 2010). For a better understanding and visualization about the structure, motivations and the aim of smart cities, table 2 presents the main concepts found in literature.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year of Publication</th>
<th>Concept</th>
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<tbody>
<tr>
<td>Partridge</td>
<td>2004</td>
<td>A smart city is a city that uses technology to guarantee citizens access to services and allow them to keep in touch with their surroundings in a simple and cheap way.</td>
</tr>
<tr>
<td>Chen</td>
<td>2010</td>
<td>Smart cities aims to optimize the infrastructure and logistical operations of cities from communications and sensor capacities, thereby improving the quality of life for everyone.</td>
</tr>
</tbody>
</table>
In view of the above-mentioned examples present in Table 2, it can be concluded that smart cities models are based on the use of Information and Communications Technology (ICT) (GRAHAM; MARVIN, 2001) to manage and regulate city flows (MAYE, 2017), increasing efficiency, safety and convenience; (BRAUN et al., 2018) using fundamental concepts that are instrumented, interconnected and intelligent (HARRISON et al., 2010); aiming to achieve city development with greater competence in the triple bottom line: social, economic and environmental (HOLLANDS, 2008; KUMAR et al., 2018).

There are several components that build a smart city, which can vary in different levels from one model to another according to the focus of each one (MOHANTY, CHOPPALI and KOUGIANOS, 2016). These components constitute several domains of the city where the meaning of the label "smart" has different connotations in each domain (OSMAN, 2019);
mostly, smart cities proposals consist of four main attributes: sustainability, quality of life, urbanization and smartness, under which some sub attributes are related (SILVIA; KHAN; HAN, 2018).

Giffinger et al. (2007) argue that although the term smart cities are understood as a certain capacity of a city and does not focus on unique aspects, an additional definition requires the identification of certain characteristics for the assessment. When analyzing success factors of smart city initiatives. Chourabi et al. (2012) categorized the critical factors under eight categories to create a framework that can be used to characterize how to envision a smart city and design initiatives: management and organization, technology, governance, policy, people and communities, the economy, built infrastructure and the natural environment.

Mohanty; Choppali; Kougianos (2016), on the other hand, present in their article nine components: smart infrastructure, smart buildings, smart transportation, smart energy, smart health care, smart technology, smart governance smart education, and smart citizens. Despite the various components that integrate smart cities, Lim; Kim; Maglio (2018) summarize that the popularity of these models in scientific literature and in international politics can be attributed to the fact that they are known for improvements in six major dimensions, which were initially defined by Giffinger and Gudrun (2010): economy, mobility, environment, people, living standards and governance of cities.

City governance is complex since it is composed of several agents and stakeholder groups that are often driven by conflicts of interest (ZANELLA et al., 2014). Ruhlandt (2018) define smart city governance as a procedural interaction between stakeholder groups, each with a place in the organizational structure and with its well-defined responsibilities, provided with available technology and accessibility to the data required for the purpose of obtaining substantial results or the necessary changes.

Smart City Governance is recurrently placed at the centre of the discussion of the models — almost all approaches to developing indicators for smart cities include smart governance as an important dimension (ANAND; NAVÍO-MARCO, 2018; FERNANDEZ-ANEZ; FERNÁNDEZ-GÜELL; GIFFINGER, 2018), since they tend to lead the development of other SC dimensions and it has been a key factor within the smart cities panorama when
analysing the successful implementation of smart strategies (PALOMO-NAVARRO; NAVÍO-MARCO, 2018).

In Smart Economy dimension, existing resources are applied in the development and implementation of innovative solutions, from which human capital — as knowledge, skills and creativity turn ideas into valuable processes, products and services, in an efficient and enterprising way, with social responsibility and ‘green’ growth, while also boosting productivity and integration with the global economy to raise competitiveness.(KUMAR; DAHIYA, 2016; LI et al., 2019; SCHAFFERS, 2011; ZYGIARIS, 2013).

Smart Environment involves the use of technological tools to improve critical aspects of city living such as waste disposal, food growth, pollution control, smart electric grids, housing quality and facility management (APPIO et al., 2018). In this dimension, city leaders should explore opportunities to innovate technologies to enhance the natural environment (COLLDAHL; FREY; KELEMEN, 2013). The Smart People factor involves several aspects such as affinity to lifelong learning, social and ethnic plurality, flexibility, open-mindedness, and participation in public life. Other elements such as creativity, human capital and cooperation are also cited as factors with potential to solve problems related to urban agglomerations and others (ALBINO; BERNARDI; DANGELICO, 2015; BARON, 2012; NAM; PARDO, 2011).

The notion of Smart Living implies delivering a better quality of life for these citizens through the provision of new and improved services such as cultural facilities, health conditions, individual safety, housing quality and education facilities, in order to promote social cohesion and security, as well as to highlight tourist attractions (LETAIFA, 2015; PELLICER et al., 2013). In the matter of transport, authors as Silva; Khan; Han (2018) and Mohanty; Choppali; Kougianos (2016) argue that traditional transports — such as road transportation, train transportation, airline transport, and water transport — have existed for a long time, but with the limitation of operating independently, making global usage difficult. Mobility consists in public transportation, daily commutes using private vehicles, leisure travel, among others. Thus, Intelligent Transport Systems (ITS), whose focuses on deploying IoT networks to address transportation with respect to varied functionalities and applications may
provide wide accessibility and efficiency to citizens of smart cities, regardless of any physical, sensorial or cognitive limitations (ALAVI et al., 2018).

The rapid technological advance presents great potential to support achievement of the Sustainable Development Goals (SDGs) (UNITED NATIONS, 2018). The way people use and see technology must be changed in sustainable ways, so that, what makes a smart city and what constitutes a sustainable one may act in synergy, where the smart city is not just about smart infrastructure but also the extent to which such infrastructure assists in achieving sustainable development objectives (ESMAEILIAN et al., 2018).

3. Sustainable Cities

The 21st Century is considered by some authors as the century of the cities, since the urban world population surpassed the rural population for the first time in 2008 (NEVENS et al., 2013). Urbanization is an ongoing process: there were 371 cities with more than 1 million residents in 2000; 548 in 2018 and 706 are projected by 2030 around the world - 43 of which will be megacities, meaning they will have at least 10 million inhabitants (UN, 2018).

Urbanization is a reality of the 21st Century, not a choice. Therefore, it is not possible to choose whether urbanization will happen, but how it will happen (SETO et al., 2010).

Urbanization has several positive impacts on mankind. For instance, urban centres that are agents of change (SETO et al., 2010) that drive the economy (STRATIGEA et al., 2017), increase employment and social welfare levels (OCHOA et al., 2018) and are innovation poles and basic services providers (NEVENS et al., 2013). However, they can pose a number of challenges such as an increase of pollution and use of non-renewable energy (DE ANDRADE GUERRA et al., 2016), as well as environmental degradation, compounding climate change (OCHOA et al., 2018), increasing number of slum dwellers (UN DESA, 2018); greater vulnerability to natural disasters (UNITED NATIONS, 2017) and production of 80% of greenhouse gases (YIGITCANLAR et al., 2018).

In response to that, a concept of sustainable urbanization has emerged to solve problems in cities and problems caused by cities (OCHOA et al., 2018). The concept of sustainable city emerges as a city able to meet the basic needs of their population, considering the current
generation and future generations (IBRAHIM et al, 2015). Based on what was presented previously, Table 3 presents the main concepts of Sustainable Cities collected in literature.

Table 3 - Sustainable Cities main concepts

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year of Publication</th>
<th>Concept</th>
</tr>
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<tbody>
<tr>
<td>Bond and Morrison-Saunders</td>
<td>2011</td>
<td>A sustainable city is the one composed by a relation of several subsystems seeking to promote welfare for its population.</td>
</tr>
<tr>
<td>Ibrahim et al.</td>
<td>2015</td>
<td>A sustainable city could be seen as a city that is able to meet basic needs of their inhabitants, such as infrastructure, civic services, health and medic assistance, housing, education, transports, jobs and good governance, with benefits to all sectors of society.</td>
</tr>
<tr>
<td>de Andrade Guerra et al.</td>
<td>2016</td>
<td>Sustainable cities are those which meet specific requirements and characteristics structured within efficient and sustainable policies. They are the path to implement policies that can help meeting needs of future generations.</td>
</tr>
<tr>
<td>Martos et al.</td>
<td>2016</td>
<td>A sustainable city must not only integrate methods to mitigate their effect on the environment, but also become a space which promotes a better quality of life for its citizens, promoting active participation in the development of the means to satisfy their needs in a sustainable way.</td>
</tr>
<tr>
<td>Bibri</td>
<td>2018</td>
<td>Sustainable city can be understood as a set of approaches into practically applying the knowledge of urban sustainability and related technologies to the planning and design of existing and new cities or districts</td>
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</table>

Source: Elaborated by the authors, 2019

Sustainable development has several areas and the urbanization is able to gather most of them (SOFESKA, 2016). The World Bank suggests that urban sustainability can be achieved with good governance, financial sustainability, economic growth, mitigation of greenhouse gas emissions and poverty reduction (GLOBAL PLATFORM FOR SUSTAINABLE CITIES, 2018), whilst others authors as Ibrahim et al (2015) divide the areas in the three main pillars of sustainable development: environmental, economic and social. The following paragraphs will present some of the categories found in the literature about the implementation of sustainable cities, in addition to explaining their relevance to the topic addressed.

Urban areas cause profound environmental changes locally (SETO et al, 2010). One factor that impacts the environmental aspect of the cities is waste production, since the increase
in consumption caused by urbanization and population growth result in more waste (BUGGE; FEVOLDEN; KLITKOU, 2018); thus, cities concentrate residue production (NEWMAN, 2006). The presence of residues on the streets can contaminate water and soils (COSTA; ALFAIA; CAMPOS, 2019), as well as spread diseases and worsen natural disasters such as floods, making residue collection essential (UNITED NATIONS, 2017).

Waste treatment is also an important issue: burning waste or storing it in landfills is still a common practice in countries such as Brazil, for example, which improperly disposes of 80 tonnes of waste on a daily basis (COSTA; ALFAIA; CAMPOS, 2019). This can be seen as a waste of energy since it can be recovered through recycling and reuse processes (BUGGE; FEVOLDEN; KLITKOU, 2018).

Another fundamental aspect to achieve sustainability in cities is governance, which can be understood as a series of legal and administrative measures to provide services (CHOURABI et al., 2012). Cities are providers of basic services (NEVENS et al, 2013), however, there is still a lack of basic services worldwide: there are 2.5 billion people in the world without access to basic sanitation, 780 million people without access to safe water and 270 million without access to electricity (UNEP, 2018). Since 1990, the number of people living in slums has increased in absolute numbers (UNITED NATIONS, 2017).

In the economic field, several authors have observed a correlation between sustainability and a good performance in the economy. The Lisbon Ranking, created to measure Smart Sustainable Cities (SSCs) in Europe (AKANDE et al, 2019), concluded that richer cities (using GDP per capita as a measure) perform better in the ranking. Environmental sustainability is one of the main components of UN-Habitat's City Prosperity Index, given that prosperity and environmental sustainability of cities are inextricably linked (YIGITCANLAR; DUR; DİZDAROGLU, 2015).

Sustainable Cities also need to pay attention to the issue of transportation. Although there is no consensus in the literature on how to measure and evaluate sustainable transport, current traffic and trends are not sustainable in the long run (STEG; GIFFORD, 2016). The main problem is the oil dependence: 96% of transport in the European Union depends on oil or oil products, but it is a scarce resource. In a few years, even if it does not end, oil will become
gradually more expensive as it is necessary to seek other options (EUROPEAN COMISSION, 2011) such as encouraging bicycles or public transport. The availability of varied and accessible public transportation is a trademark of Sustainable Cities (DE ANDRADE GUERRA et al., 2016).

However, when it comes to transportation, it is not only the vehicles that need to change, but changes in the streets are also necessary, as evidenced in the concept of Complete Streets, which advocates that streets should be designed and constructed not only based in cars, but providing infrastructure for pedestrians, cyclists and bus users (MCCANN, 2011) The construction of Complete Streets brings several benefits to the communities: in Muskogee, Oklahoma, in the United States, some of the expected results of the Complete Streets policy were to increase the number of cycle paths, reduce the number of traffic accidents and fatalities and increasing the number of people walking and cycling, including children (SMART GROWTH AMERICA, 2017)

Sustainable Cities can seek through technology capacities ways to change social behavior toward a pro-environmental behavior. In this sense, the potential of Smart Cities for the remediation of environmental problems is an important issue that must be studied (ESMAEILIAN et al., 2018). In recent years, cities have targeted in smart cities goals instead of sustainability goals, even though they are interconnected and share similar goals (AHVENNIEMI et al., 2017). Thus, there is a need to better understand the relation between them. The next topic will address the relationship between the concepts of Sustainable Cities and Smart Cities.

3.1 Smart Sustainable Cities

While smart cities are projected, expectations grow that their policies will reduce impacts from this fast urbanization and drive sustainable development (KUMMITHA and CRUTZENB, 2017; VIITANEN; KINGSTON, 2014). However, there is no agreement in literature that the concept of smart cities as a whole does emphasize concerns of sustainability (DE JONG et al., 2015; MARTIN et al., 2018). Solutions in these models have been criticized for being often too techno-centric, driven by technology companies’ own agendas while
lacking proper attention to cities’ needs and environmental issues (HUOVILA; BOSCH; AIRAKSINEN, 2019). These concerns have opened the way for a new term.

The idea of Smart Sustainable Cities (SSCs) has emerged in literature matching urban sustainability and smartness, considering them equally important (HUOVILAA; BOSCH; AIRAKSINENC, 2019). These models use Information and Communication Technologies (ICTs) as their basis to improve quality of life and deliver efficient services in urban environments, keeping in sight the need to ensure it meets the needs of present and future generations with respect to economic, social, environmental and cultural aspects (ITU, 2019).

Hara et al. (2016) argue in their study that there is a need to create key performance indicators to evaluate a SSC based on sustainable development and its triple bottom line: social, economic and environmental factors. Ahvenniemi et al., (2017) state that one of the main goals for SSCs is to improve sustainability with help from all available technologies, as ICTs are increasingly used to implement sustainability in urban centers. Ibrahim et al. (2018) found several roadmaps for urban centers to become SSCs in literature; however, none of them covers all spheres as necessary; for instance, not evaluating current challenges for a city or evaluate city readiness for change. Then, a coherent and systematic model is needed to capture the transversal readiness of a city in its infrastructure, to understand essential aspects in transforming cities.

Bibri et al. (2018) argue that SSCs are built in a socially constructed understanding and in socially anchored practices regarding ICTs use in urban sustainability, so they are shaped by and can shape socio cultural structures and policy-making. The success of SSCs derives from transformational powers, relations of knowledge, workforce, capacity of ICT legitimization and a new wave of computational innovation regarding urban sustainability. Authors claim that ICT must be directed towards an environmental regard on sustainability, solving complex environmental issues and creating a holistic approach to urban development.

Developing a SSC requires an efficient and effective transformation process, considering aspects such as city context and needs, local interests, population quality of life and smart sustainable solutions that need to be delivered in all levels in cities (IBRAHIM; ADAMS; EL-ZAART, 2015). SSCs present a new way of considering and optimizing available
and new resources, a purpose that can be achieved through the support of various information and communication technologies (LAZAROIU; ROSCIA, 2012). In this context, Industry 4.0 emerges as a powerful force which is expected to change urban development and future cities (ESMAEILIAN et al., 2018). Based on this discussion, Table 4 presents the main concepts regarding SSCs found in literature.

Table 4 - SSC main Concepts

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<th>Author</th>
<th>Year of Publication</th>
<th>Concept</th>
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<tbody>
<tr>
<td>ITU</td>
<td>2010</td>
<td>A SSC can be considered as an innovative city using ICTs as a way to improve quality of life, service efficiency and urban operations in economic, social and environmental spheres.</td>
</tr>
<tr>
<td>Bibrie and Krogstie</td>
<td>2017</td>
<td>A SSC is the one capable of integrating effectively ICTs with existing city designs to improve urban sustainability.</td>
</tr>
<tr>
<td>Hara et al.</td>
<td>2016</td>
<td>A SSC is defined as an integration of multiple technologies to improve human quality of life using services as security and infrastructure.</td>
</tr>
<tr>
<td>Ibrahim et al.</td>
<td>2018</td>
<td>SSCs are the ones that use technologies of innovation and communication to help implementing sustainable development in urban centers. SSCs can be divided in six categories: Smart Economies, Smart Environment, Smart Governance, Smart Living, Smart Mobility and Smart People.</td>
</tr>
<tr>
<td>Aina</td>
<td>2017</td>
<td>The concept of SSC is related to using opportunities brought by ICT to help achieving sustainability in urban centers.</td>
</tr>
</tbody>
</table>

Source: Elaborated by the authors, 2019

As seen in Table 4, several concepts on SSC regarding the use of ICTs to implement sustainability in urban centers. This process can happen in several ways. Kramers et al. (2014) show that ICT contributes reducing energy consumption in cities using an analytical framework, where a typology is made for ICT opportunities and another to domestic opportunities regarding energy use. This analytical framework might be useful policy-makers in cities, regions and nations, as well as ICT companies, who are interested in understanding how ICTs investment might help reducing energy use in cities. The use of evaluation tools can be done in cities as a support for urban decision-making, since they allow cities to use methodologies to evaluate their progress comparing it to their targets (AHVENNIEMI et al.,
The building of SSCs are being increasingly supported by governments and companies as one of the more effective ways to promote urban sustainability (MARTIN et al., 2018).

4. Fourth Industrial Revolution

The increasing demand for capital and consumption of goods in the globalized world requires opportunities for the realization of advanced manufacturing (MAYNARD, 2015) that makes it possible to guarantee a production system that is both viable and sustainable (CARVALHO et al, 2018) to meet the needs of the population. For several hundred years, the industrialization process has been shaped, making manufacturing processes increasingly complex, automatic and autonomous (LU, 2017).

In the 19th century, the first industrial revolution transformed manufacturing processes with steam-powered mechanical equipment. In the early part of the 20th century, the use of electric power to drive production lines made possible the mass production, qualifying the second industrial revolution. Finally, in the 1970s, the third industrial revolution was characterized by the automation of production from the application of electronics and Information Technology (IT) (LOM et al., 2016; LUKAC, 2015).

The concept “Industry 4.0” was formulated in 2011 by the President of the World Economic Forum in Davos, Klaus Schwab (FESHINA et al., 2018) as a propose for developing German economy (LU, 2017), based on high-tech strategies (MOSCONI, 2015), combinating Internet of Things (IoT), Cyber-physical Systems (CPS) and Internet of Services cooperating with each other and with human within a system (CHUNG and KIM, 2016). Therefore, the differential of this fourth wave of technological advances is the very close interaction between physical, digital and biological worlds (SYAM; SHARMA, 2018).

This new conception is not just about industry, but is about overall transformation using digital integration and intelligent engineering (MUHURI; SHUKLA; ABRAHAM, 2019). Industry 4.0 is rooted in the advanced manufacturing or also called Smart Manufacturing concept, in which work in progress products, components and production machines will collect and share data in real time, increasing the automation of manufacturing and the integration in which planning, control and decisions are decentralized, taking the entire product lifecycle and
supply chain activities to a new level. (FRANK; DALENOGARE; AYALA, 2019; GILCHRIST, 2016; LEE; BAGHERI; KAO 2015; SHROUF; ORDIERES; MIRAGLIOTTA, 2014; WOLLSCHLAEGER; SAUTER; JASPERNEITE, 2017).

This fourth wave of technological advancement is powered by nine foundational technology advances — many of them are already used in manufacturing, but in this new system optimized cells will come together as a fully integrated, automated and optimized production flow, leading to greater efficiencies and changing traditional production relationships (RÜßMANN et al., 2015). In the following table (5) the nine technology trends that are the building blocks of Industry 4.0 are presented and conceptualized based on the literature.

<table>
<thead>
<tr>
<th>Term</th>
<th>Concept</th>
<th>Authors</th>
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<tr>
<td>Big Data and Analytics</td>
<td>Composed of characteristics called “V”s – such as volume, velocity, variety and veracity - Big Data is a term that refers to the a large growing data sets that are collected using digital communication devices from satellites to smart phone applications, stored in computer databases and ‘mined’ by computer advanced algorithms.</td>
<td>SURBAKYI et al., 2019; BRONSON, 2018; OUSSOUS et al, 2018</td>
</tr>
<tr>
<td>Autonomous Robots</td>
<td>The progress of technology enables researchers to create advanced machines that can perform increasing number of tasks autonomously without human control and supervision. in this sense, intelligent autonomous systems operating in physical environments, the so-called autonomous robots which has long been used in manufacturing, are becoming more autonomous, flexible and cooperative. These robots will eventually cost less and have a greater range of capabilities than those used today.</td>
<td>ZŁOTOWSKI; YOGESWARAN; BARTNECK, 2017; AMIGONI et al., 2017; RÜßMANN et al., 2015</td>
</tr>
<tr>
<td>Simulation</td>
<td>In the 4.0 industry context, simulations will be used more extensively in plant operations to mirror the physical world in a virtual model, which can include machines, products and humans, reducing the time of configuration of the machine, shortening downtime, reducing production failures and increasing the quality and speed of decision making.</td>
<td>VAIDYA et al., 2018; SYAM; SHARMA, 2018; PAWLEWSKI, 2018</td>
</tr>
<tr>
<td>System Integration: Horizontal and Vertical System Integration</td>
<td>The technological breakthroughs behind the 4.0 revolution require corporations to adapt their production mode with the aim of creating operational synergy and providing competitive advantages within the value chain production system.</td>
<td>SAUCEDO-MARTINEZ et al., 2018; MARMOLEJO, 2018</td>
</tr>
</tbody>
</table>
The main concept of Internet of Things (IoT) is to connect smart objects within cyber physical systems, where objects will interact with each other and can be supervised remotely by users. With this in mind, a definition of Industrial Internet of Things (IIoT) may be the use of certain IoT technologies in an industrial setting/manufacturing, for the promotion of goals distinctive to industry.

Cyber Physical systems (CPS) arise through devices for interaction between computing objects, people and the physical environment, and include systems such as Smart grids. Enabled with IOT, the CPS helps in the process of collecting, storing and managing data.

The integration between IOT and the cloud with respect to revolution 4.0 can help in the unfolding of data management problems, in a way that guarantees better accessibility and viability of the services. Cloud computing enables delivery of hosted services to be delivered more efficiently through a software development platform to process the large amount of data generated by IOT.

Additive layer fabrication is used to construct or assemble parts so that the product prototype can be available quickly and changed according to the customer's needs. With the advances of the fourth industrial revolution and the increasing technological adaptation, the capacity of the Additive manufacturing has grown from the optimization of configurations.

Through Revolution 4.0 augmented reality has become one of the most exciting technologies to invest due to the emerging concept of intelligent manufacturing and can be used as a support for maintenance operations.

The fourth industrial revolution is in course and is expected to significantly affect the way individuals live and in result change the society in various aspects (CHUNG; KIM, 2016). The possibility of billions of people connected by mobile devices with powerful processing and storage capacity, as well as access to knowledge are unlimited, and will be enhanced by the advancement of technology in fields, such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage and quantum computing (WORLD ECONOMIC FORUM, 2019).

5.1 Impacts of the Fourth Industrial Revolution on Smart and Sustainable Cities

Cities do not grow in a vacuum, on the contrary, following the trends of globalization they coexist, collaborate, compete and evolve on different scales with reference to each other. In this sense, its position in the global ranking and the consciousness of acting as a part of a transnational urban network as a part of a transnational urban network can feed the local urban
policy agenda by providing new insights to the policy-makers about the (global) urban function (TRANOS; GERTNER, 2012). In light of this, the development of ICT-based communication and other industry technologies 4.0 do not make distance a determining factor in the urban collaboration.

Figure 1 presents a word cloud with the function of showing the terms more frequently in 7 articles that presented the main concepts found in the literature on Smart Cities according to table 1. The word cloud allows the text to be represented visually, and illustrates the frequency of the terms, directly proportional to the size in which they appear in the image (DLOUHA; POSPISILOVA, 2018).

Figure 1 - Smart Cities Word Cloud

Source: Elaborated by the authors, 2019

Based on figure 1, it is possible to analyze which terms have the highest incidence in the 7 articles analyzed. It can be seen that several terms involving the importance of technology for the consolidation of Smart Cities have a similar frequency, such as Smart, Services, Information, Research, Systems, Data, Internet, Urban, Network, Model, Digital, Digital divide. The terms with the highest incidence represent what the authors of the articles analyzed present in their studies as main factors about smart cities. Partridge (2004) argues that the use of digital technologies is a complex phenomenon and that the development of a more
sophisticated understanding of this phenomenon will aid in the organization of public policies that aid in the deployment of intelligent cities. Whilst for Chen (2010), the smart grid will depend on a digital communications network, which can intelligently and regularly monitor how households and industries in a municipality use base resource assets such as water and energy. In this way, smart cities will be able to take advantage of the communication resources available as sensors directly linked to the urban infrastructure to optimize their operations, so that the quality of life of their inhabitants is improved.

Cities are becoming smarter as governments, businesses, and communities gain more reliance on technologies as a means of assisting the challenges faced by rapid population growth, from which Washburn et al. (2010) points out that what makes urban centers as smart is the combined use of software systems, server infrastructure, and client devices that can better connect municipal infrastructure services such as education, health, public safety, real state, transportation and public services. This is because the concept of smart cities is pushing governments, whether state, local or regional, to evaluate emerging technologies and engage with key stakeholders both inside and outside organizations.

Harrison et al. (2010) states that the cities that can be considered smarter are those that explore the operational data to optimize the operation of the city services, where the fundamental concepts pass to be intelligent, interconnected and instrumented. This approach has the capacity to adapt the municipal services to the behavior of the inhabitants, which allows a better optimization and the use of the infrastructure of all available resources to promote a better quality of life for the citizens.

Whilst for Bakici et al. (2012) information and communication technologies are adapting the way cities organize and formulate their policies directed towards urban growth, smart cities are based on the use of technologies in various fields, such as economy, education, security, urban mobility, among others. All cities have size, culture, population, form and function that differs them. Based on this, Zygiaris (2012) presents the study of a model that can be used in different realities and adapted to the policies necessary for each city, in order to address the characteristics of intelligent innovation ecosystems that will elucidate the understanding about the sustainable cities. These paradigms have the task of addressing
challenges that are related to global sustainability in a local context, and it is important to highlight that intelligent city planners can adapt innovation characteristics according to their needs.

As smart cities are known as urban environments where the ITC system supports them, Piro et al. (2014) argues that the use of JTIs can provide the urban community with advanced and innovative services, and points that the importance of developing a platform the ITC service. Thus, this model should have the ability to span all available wireless technologies and be the start of a new business, as well as evidences the real purpose and importance of creating intelligent environments. After analyzing the importance of the terms, and their frequency, was developed the figure 2 that presents a graph of interdependence on the terms.

Figure 2 - Graph of interdependence on Smart Cities Terms

Source: Elaborated by the authors, 2019
As can be seen in Figure 2, all terms have a direct connection to each other, however those that present a greater interdependence are: Support, Cities, Net, Network, Quality, Technologies, Communications, Communication, Information, Digital, Data, Energy, Life, Environment, Smart, Connect, City and Design. A theoretical justification for the strongest relationship between the terms can be found in several articles such as when Brock et al. (2019) presents in his study that for the implantation of intelligent cities sufficient support is necessary so that the use of IOT and ICT is possible so that the quality of life of the population is assured. Whilst for Sharma; Park (2018), the construction of intelligent cities is due to the autonomous and distributed infrastructure that includes from intelligent systems of information processing and control to the heterogeneous network infrastructure and detection of the source of information. In this way, the network must be used to meet the demands and overcome the limitations by designing a distributed architecture in a safe, efficient and effective way in the implantation of sustainable cities.

Figure 3 corresponds to a word cloud, which has the function of presenting the terms with higher and lower incidence in the five articles analyzed for the construction of table 3 that presents the main concepts found in the literature about sustainable cities. The word cloud is a weighted list model that serves to analyze data of language or text, which presents the size of the words according to their repetition in the text (JIN, 2017).

Figure 3 - Sustainable Cities Word Cloud
As seen in Figure 3, there are several terms in the word cloud that present a similar frequency, such as Systems, Planning, Environmental, Sustainable, Urban, Development, Cities, Smart, Policy, Data, Economic, Human, Energy and Environment. Based on these results, it is possible to analyze how authors present the main terms regarding the building of a sustainable city. Bond; Morrison-Saunders (2011) present Sustainable Development as the main goal in the field of expansion of sustainability evaluation, arguing that sustainability evaluation practices are based in particular frameworks of political controversies; whilst one of its main goals is to help deliberation on these controversies, creating a movement towards a new sustainability thinking, encompassing all these different ideas.

Ibrahim et al. (2015) add that there are several studies on the complexity of sustainable cities implementation around the world, including a need for creating indicators and tools to measure sustainability levels in urban centers, considering that indicators are measures which provide summaries of information. De Andrade Guerra et al. (2016) states that urban centers are important drivers in promoting strategies to implement sustainable development. Authors analyze differences in urban mobility in two cities: Newcastle upon Tyne (United Kingdom) and Florianópolis (Brazil), comparing factors such as social and economic indicators, gross domestic product (GDP) per capita, inflation, employment and population growth historical
numbers in these cities. This comparison is made to create models, ideas and actions on sustainable transport.

Martos et al. (2016) argue that current population growth levels in urban areas, especially in developing countries contribute to the fact that cities correspond to 80% of greenhouse gas emissions, further enhancing the need to implement sustainable cities. Decisions regarding sustainable city management and planning must be made whilst evaluating consequences. Bibri (2018) states that underlying theories are the basis for sustainable city practices. Academic research in this field acts in believing that advances in this underlying knowledge demands the creation of questions that can only be answered in a multifaceted fashion, using ICT. As observed, all authors mention the importance of implementing sustainable cities for promoting sustainable development. Based on this, Figure 4 presents a chart of interdependence of terms analyzed in literature used for creating the word cloud.

Figure 4 - Chart of Interdependence on Sustainable Cities

Source: Elaborated by the authors, 2019
After analyzing the main terms about sustainable cities and smart cities and the relationship between the terms, in order to respond to the goal proposed by the research, it is necessary to analyze how each pillar of globalization 4.0 has affected the implantation of sustainable cities. Table 6 shows how this relationship can occur.

**Table 6 - Interdependence between pillars of the Fourth Industrial Revolution and SSC Implementation**

<table>
<thead>
<tr>
<th>Technology category</th>
<th>Big Data and Data Analytics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Ideas</strong></td>
<td>Big data and data analytics (BDA) are applied in many different domains within smart cities. Big Data Analytics tools help analyze real data to enhance productivity and reduce the uncertainty in decision making process. It can be applied in the most diverse dimensions of cities and companies, such as manufacturing, pharmaceutical and health areas, transportation, governance and energy.</td>
</tr>
<tr>
<td><strong>Authors</strong></td>
<td>CARAGLIU et al., 2011; HASHEM et al., 2016; ANISETTI et al., 2018; ZHONG et al., 2017; PRAMANIK et al., 2017</td>
</tr>
<tr>
<td>Technology category</td>
<td>Autonomous Robots</td>
</tr>
<tr>
<td><strong>Main Ideas</strong></td>
<td>Provision of public and personal services for citizens and the use of new tools used for professional for operating in urban settings.</td>
</tr>
<tr>
<td><strong>Authors</strong></td>
<td>SALVINI, 2018; BOYSEN, SCHWERDFEGER; WERIDINGER, 2018</td>
</tr>
<tr>
<td>Technology category</td>
<td>Simulation</td>
</tr>
<tr>
<td><strong>Main Ideas</strong></td>
<td>Simulations are a powerful tool because, potentially, they provide the designers of the experiments full control over all the variables of the settings. Simulations are made in several aspects, examples can be cited in the field of safety as a mean to support decision-making during real emergencies.</td>
</tr>
<tr>
<td><strong>Authors</strong></td>
<td>LACINAK and RISTVEJ, 2017; AMIGONI, LUPERTO and SCHIAFFONATI, 2017</td>
</tr>
<tr>
<td>Technology category</td>
<td>System Integration: Horizontal and Vertical System Integration</td>
</tr>
<tr>
<td><strong>Main Ideas</strong></td>
<td>Through better operational synergy and competitive advantages, the technological advances resulting from the revolution 4.0 allow the needs of an SSC to be better managed</td>
</tr>
<tr>
<td><strong>Authors</strong></td>
<td>SAUCEDO-MARTINEZ et al., 2018; MARMOLEJO, 2018</td>
</tr>
<tr>
<td>Technology category</td>
<td>The Industrial Internet of Things</td>
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<tr>
<td>Main Ideas</td>
<td>The Internet of Things (IoT) can be considered one of the main components in ICTs for SSCs, as an approach of urban development due to its great potential to promote sustainability in urban centers. IoT is directly associated with Big Data and can be used in several sectors of city management, as optimizing energetic efficiency and mitigating environmental problems, besides working in areas such as waste management practices. The use of IoT and Big Data can play an important role in catalyzing and improving sustainable development.</td>
</tr>
<tr>
<td>Authors</td>
<td>BIBRI, 2018</td>
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<table>
<thead>
<tr>
<th>Technology category</th>
<th>Cyber security and Cyber Physical Systems (CPS)</th>
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<tbody>
<tr>
<td>Main Ideas</td>
<td>Cybernetic Physical Systems (CPS) allow integration between computing objects and the environment, it can be used in the implementation of SSC, as facilitators of social well-being, and improving the quality of life of the population, through a better integration between systems</td>
</tr>
<tr>
<td>Authors</td>
<td>PARASOL, 2018; BAIG et al., 2017; JIN et al., 2016.</td>
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<thead>
<tr>
<th>Technology category</th>
<th>The Cloud</th>
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<tbody>
<tr>
<td>Main Ideas</td>
<td>The Cloud works as an efficient and economic tool to allow to process, manage and storage data, contributing for SSCs to have information on city management stored in a safe environment, allowing a better management of available resources.</td>
</tr>
<tr>
<td>Authors</td>
<td>KRAMERS et al., 2019; SUN et al., 2019; LIAQAT et al., 2017; ZHANG et al., 2018; NOWICKA et al., 2016</td>
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<tr>
<th>Technology category</th>
<th>Additive Manufacturing</th>
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<tr>
<td>Main Ideas</td>
<td>Additive manufacturing can contribute to the deployment of a smart and sustainable city, as it allows new consumption needs where products need to have a lower environmental impact is possible.</td>
</tr>
<tr>
<td>Authors</td>
<td>MA et al., 2018; GHOBADIOAN et al., 2018; CRAVEIRO et al., 2019; PRIARONE et al., 2017</td>
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<tr>
<th>Technology category</th>
<th>Augmented Reality</th>
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<tr>
<td>Main Ideas</td>
<td>The use of Augmented Reality in the context of SSC implementation can happen in several way to improve quality of life in communities, providing better inclusion for disabled people and creative solutions such as wearable technologies to help in the population's consumption needs.</td>
</tr>
</tbody>
</table>
Modern information and communication technology systems are critical to the development of smart sustainable cities, once SSCs involve the deep integration of ICT in all aspects of city life and operation to improve the standard of residents’ living (LU; CHEN; YU, 2019). Smart Sustainable Cities combine technological from the fourth industrial revolution with the demand for cyber–physical applications in areas of public interest (ESPOSTE et al., 2019) to improve the local economy, transport, traffic management, environment and interaction with government (ISMAILOVAILOVA et al., 2019) from the implementation of strategies that will be presented and discussed in the following paragraphs.

Cities around the world collect massive amounts of data related to urban living, and these data contribute to the production of useful information that can be used to improve several aspects of cities (CARAGLIU et al., 2011), once processing and interpretation of data is an essential tool which help to enhance productivity, enhance the services offered to citizens and reduce the uncertainty in decision making process (ALLAM; DHUNNY, 2019).

The use of big data analytics can be apply in smart service systems such as smart customization and prevention — for crime prevention, midnight bus service routing and scheduling — Smart operations management — Intelligent trash pickup, Prognostics and health management or Intelligent traffic control — Smart coaching — for Player management, Fitness tracking and Baby condition monitoring, as well as Smart adaptation and risk management — Intelligent navigation, Fleet management and Demand consulting (ANISETTI et al., 2018; MAGLIO; LIM, 2016; PRAMANIK et al., 2017).

Facility, security, access to infrastructure and quality services can be achieved through real-time analyses of city data (RATHORE et al., 2018). Once Smart city governance necessitates plurilateral collaboration among the various societal actors, Big data analytics can also play a key role, therefore, organizations or agencies with common interests can easily be identified that can lead toward collaboration among them. Moreover, big data analytics can
help governments establish and implement satisfactory policies because they are already familiar with the needs of the people (HASHEM et al., 2016; JU; LIU; FENG, 2018).

Robots are leaving factories and entering urban spaces (NAGENBORG, 2018). As shown, civil applications of robots in urban environment consists in in the provision of public and personal services for citizens and the use of new tools used for professional for operating in cities settings (SALVINI, 2018). To reduce the negative impact of excessive traffic in large urban areas, for example, many innovative concepts for intelligent transportation of people and freight have recently been developed, such as autonomous delivery robots launched from trucks (BOYSEN; SCHWERDFEGER; WERIDINGER, 2018).

In the services sphere, automated transportation systems, door-to-door rubbish collection, street cleaning, object transportation, human guidance, assistance, autonomous wheelchair, shop-trolley, are already used and consolidate trends in robotics research (SALVINI; LASCHI; DARIO, 2010). Other capabilities of urban robotics that are currently investigated can be cited, such as navigating autonomously in crowded and cluttered spaces; detecting curbs during navigation; testing human-robot interactions during autonomous navigation; testing the effectiveness of communicative skills in assistive tasks such as museum guides, concierges, shopkeepers (SALVINI, 2018).

The major challenge for the use of autonomous robots in the urban context is mostly related to aspects that consider the level of autonomy, especially the safety issue (KAHN et al., 2006; SULLINS, 2011). The autonomy issue affects the extent to which people are willing to use a robot or work with it as well as affects blame and credit attributed to a robot and its human interaction partners. In this context, it must be designed, studied and developed with attention and planning (ZŁOTOWSKI; YOGGEESWARAN; BARTNECK, 2017).

Simulation is used to imitate something substantively, which can be used for training purposes (WISELI; TANUSETIAWAN; PURNOMO, 2017). Thus, simulations can be used in SSCs as a mean to where executives of crisis management of the city will be able to train their ability to react quickly on emergency by modelling cases (LACINÁK; RISTVEJ, 2017). They can be also applied to estimate and predict resource management such as simulation of actual energy usage/efficiency (SODIQ et al., 2019), control envinmeny impacts from simulation of
city pollution (APPIO LIMA; PAROUTIS, 2019) or gain predictive insights for strategic decision–making associated with sustainability from urban simulation models (BIBRI; KROGSTIE, 2017).

System Integration can be seen as one of the greatest motivators of the Fourth Industrial Revolution, since it updates the stages of production and promotes an optimization of the industrial process (PEREZ-LARA, 2018). Alcácer; Cruz-Machado (2019) state that whilst the horizontal system presents in intercompany integration use the data storage and management created in the fourth industrial revolution to increase product lifecycle, promote exchanging data and consequently contributing in economic and sustainable spheres; the modernization of the vertical system offers a more rapid and secure communication between different sectors in the same company, causing an increase in product quality.

The integration between manufacturing systems support the growth of products quality, duration and quantity (MARMOLEJO, 2018), contributing to a more frequent emergence of technological innovations that aim the industrial development in a less environmentally harmful way, adapting companies to the needs of Smart Sustainable Cities, the achievement of economic goals and meeting the consumers requirements, once it associates production, technology and environmental awareness (ALCÁCER; CRUZ-MACHADO, 2018).

When dealing with the internet for a smart and sustainable city, the internet of things emerges as one of the main components. It is directly linked to Big Data, it can be used in various city management sectors, such as in controlling transparency portals, ensuring that people have better access to public service goods such as schools and security. In addition to assisting decision-makers to better understand the needs of their population (BIBRI, 2018).

Cyber-Physical Systems can be understood as the association of the physical environment and computing objects. Boulila (2019) states that Communication, Control and Computation are the building blocks of the concept and its three layers: business; interface; and physical. In each layer, Cyber-Physical Systems use different processes to storage, organise and management information, offering a systematic application of data to social, economic and environmental spheres, contributing to the creation of new and more rapid connections, facilitating the arising of Smart Sustainable Cities (Boulila, 2016).
In the sense of Cyber Security, Boulila (2019) highlights the its relevance once it protects information from other humans and machines; detects systematic failures; prevents from malicious attacks; and decrease the risks of infrastructure planning errors. In the context of Smart Sustainable Cities, it is fundamental for the creation of safe computational innovations regarding urban development and sustainability. However, Elmaghraby; Losavio (2014) point that Cyber Security faces several challenges, since the literature does not present a consensus regarding the limits of security and private information of users, companies and organizations, pointing to a characteristic and growing debate in the studies of the fourth industrial revolution.

As an efficient and economical tool for processing, managing and storing data, in the deployment of an SSC, the use of the cloud allows all data collected from the city to be safely allocated as energy, water and food consumption, quantity of vehicles per highway, time spent on commuting to work, so that better management of all resources can be achieved, promoting a better quality of life for the population (KRAMERS et al., 2019).

The idea behind additive manufacturing is to drastically reduce waste production and resource use in manufacturing, in order to achieve sustainability (GHOBADIAN et al. 2018). Several factors affect how each product will affect the environment, including product design and manufacturing process. With that in mind, tools can be developed in order to identify the cleanest production routes, leaving the smallest possible carbon footprint behind (PRIARONE et al., 2017). The influence of additive manufacturing goes beyond the production process; it encompasses the whole life cycle. An additive manufacturing has high impact on the economic and environmental spheres of sustainable development, while a correct end-of-life handling will have social impact (MA et al., 2018). Additive manufacturing can also be applied in the construction sector, both in projecting buildings with sustainable materials and in projecting new models of buildings that are low in consumption (CRAVEIRO et al., 2019).

Augmented reality (AR) has several implications for SSCs. For instance, it can be used to help people with motor disabilities, especially wheelchair users, to touch things beyond their arm’s length. In a study made by Rashid et al. (2016), results were promising when people with different levels of disability were evaluated in terms of digitally interacting with physical items, contributing to better include all citizens in a SSC. Another possible use of AR is to predict
scenarios, such as natural disasters. Haynes et al. (2019) propose a mobile AR application to create flood simulations, aiming to better assess flood risk management; a technology that can also be applied in other planning and designing projects.

AR systems also have several other applications that can help achieve sustainability or improve quality of life. Such systems can be used to facilitate commuter’s decisions in public transport, as finding the closest bus stops and trains, as seen in Barcelona, in Spain (APPIO et al., 2018); connect to population’s personal devices to provide useful information, such as temperature, solar radiation, rainfall, wind speed, vehicle presence and parking occupancy, as seen in Santander, in Spain (ESCOLAR et al., 2018); for creating new solutions for resource allocation in smart applications (SODHRO et al., 2019) and enhancing performance and retrieving feedback to improve maintenance (DEL AMO et al., 2019).

Conclusion

To find solutions for improving life in cities is not only desirable and important, it is vital. Most of the world’s population live in urban areas, and the world is very likely to continue its trends of urbanization and population growth in the next decades, while urban areas represent only 3% to 5% of the earth’s territory (SETO et al., 2010). Urban centers need to find models for providing quality of life and meeting the needs of this large concentration of people in a sustainable way. The 21st Century represents an era of other issues that must be addressed in cooperation, such as food security, climate change and gender inequality; while at the same time it sees the rise of new technologies and innovations with large-scale implications, represented by the Fourth Industrial Revolution.

The Fourth Industrial Revolution will have implications on several factors that are deeply connected to cities’ success in becoming sustainable: job creation, industries, innovation, environmental preservation, community involvement and accessibility. While this amount of profound changes makes it revolutionary, the Fourth Industrial Revolution is very different from the previous three, since it is foreseen and planned, which gives us a chance to shape and design it for the needs of our time. Today’s challenges for mankind are arguably more complex than they have ever been, but so are our tools.
Policy-makers have in the Fourth Industrial Revolution and its pillars some opportunities and challenges that must be faced. Big Data, for instance, could provide new information that could be mined, analyzed and used for identifying previously unseen problems; the IoT can provide new industrial innovations that can make economies thrive; augmented reality can help promoting inclusion for disabled people; and simulations can help society foresee problems and adapt to them. Smart City policies also incentive innovation that increases a city's stock of knowledge, one of the main recognized drivers of economic growth.

Those new technologies also bring fresh problems that must be addressed. It is understood that, while automation will improve industry performance, it may come at the cost of jobs; while cybersecurity issues will also emerge, as people are increasingly connected to their personal devices and share more information about themselves. There is also a potential ethical issue in allowing machines or systems into important decision-making.

Future research may explore how the Fourth Industrial Revolution can help in solving other problems and boosting the achievement of other SDGs. Each pillar in the Fourth Industrial Revolution here analyzed can be expanded to fit into SSCs categories.

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