Smart Cities in the Era of Artificial Intelligence and Internet of Things: Promises and Challenges

Amal Ben Rjab and Sehl Mellouli

Abstract The concept of smart cities is rapidly gaining momentum and worldwide attention as a promising response to different challenges of urban development, such as: lack of natural resources, pollution, traffic congestion, deteriorating infrastructure, economic decline, etc. This concept is driven, among other elements, by technology, and technology is growing so fast. The growth of technology has led to the emergence of new solutions that will transform our societies, as connected objects, self-driven cars, drones, and robots. These technologies can be used in every sphere of a city such as: urban problem-solving, natural resource management, real-time data processing, or predicting crimes, etc. However, these new technologies can pose new social, ethical, and legal challenges that can affect the society. In this chapter, through an extensive literature review of two key technologies used for smart cities development that are the Internet of Things (IoT) and Artificial Intelligence (AI), we identify the opportunities and the challenges that cities may face when adopting these technologies.

Keywords Smart cities · Artificial Intelligence · Internet of Things · Smart City opportunities · Smart City Challenges

Introduction

Currently, the world's population is growing at a rapid pace where more than 50% of the world population lives in cities (Chourabi et al., 2012; Ferraz & Ferraz, 2014). This situation can create tremendous pressure on every aspect of urban living, and pose several significant challenges pertaining to environmental and social sustainability (Ferraz & Ferraz, 2014) such as: poverty, criminality, pollution, deteriorating infrastructure, lack of resources, traffic congestion, or economic decline (Chourabi et al., 2012; De Paz, Bajo, Rodríguez, Villarrubia, & Corchado, 2016; Hui, Sherratt,

A. B. Rjab (✉) · S. Mellouli
Department of Information System, Université Laval, Québec, Canada
e-mail: amal.benrjab.1@ulaval.ca

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& Sánchez, 2017; Lee, Hancock, & Hu, 2014; Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014). To solve these problems and ensure a sustainable development and a quality of life in complex social ecosystems of urban areas (Kitchin, 2014), the concept of "smart cities" has been proposed (Neirotti et al., 2014; Taylor Buck & While, 2017). This concept has attracted considerable attention in the last years (Chourabi et al., 2012; De Paz et al., 2016; Ferraz & Ferraz, 2014; Hui et al., 2017; Kitchin, 2014; Lee et al., 2014; Neirotti et al., 2014; Taylor Buck & While, 2017) from both science and industry. Despite the definitions proposed in the literature to describe this concept, it is still vague (Harrison & Donnelly, 2011; Hollands, 2008; Solanas et al., 2014).

In fact, with the emergence of information and communication technology (ICT), smart cities have been viewed as intelligent digital ecosystems installed in urban areas (Gabrys, 2014) "that seek the technological advances" (Viitanen & Kingston, 2014, p. 1), such as: AI, IoT, blockchain, and cloud computing to ensure a "new era of optimized smart infrastructural management" (Taylor Buck & While, 2017, p. 503) in order to solve urban problems including traffic management, healthcare, energy crises, and many other issues (Luque, McFarlane, & Marvin, 2014; Nigon, Glize, Dupas, Crasnier, & Boes, 2016; Tang et al., 2015).

Several studies (De Paz et al., 2016; Hui et al., 2017; Nigon et al., 2016; Tang et al., 2015; Viitanen & Kingston, 2014) show that currently the technological infrastructure of smart city can be based on IoT and AI that may represent key elements for smart cities development. In order to understand the roles of these technologies in a smart city development, we discuss in this chapter, through an extensive literature review realized during the period 1990 and 2017, the opportunities and the challenges that cities will face when adopting these two technologies (IoT and AI).

This chapter is organized as follows. First, we describe the opportunities that can be generated by smart cities for a sustainable environment (section "Smart Cities: Opportunities for a Sustainable Environment"). Next, we present the methodology adopted to achieve the literature review (section "Research Methodology"). Then, we discuss the results of the literature review (section "Findings"), and we shed light on the role of AI and IoT in smart cities development (section "Opportunities of AI and IoT in Smart Cities"). Afterwards, we present the challenges that cities will face when adopting these technologies (section "Challenges of IA and IoT in Smart Cities"). Finally, we provide the main conclusions, the limits of this study, and some future thoughts (section "Conclusion").

Smart Cities: Opportunities for a Sustainable Environment

According to the United Nations Population Fund, 2008 was the year when more than 50% of all people, 3.3 billion, are living in urban areas, and this percentage is expected to rise to 70% by 2050 (UN, United Nations, 2008) (where the world population will reach up to a limit of 9.7 billion by the end of 2050). This rapid transition to a highly urbanized population creates several problems such as: air

pollution, mental health problems, crime, loss of public space, land consumption, pollution, deteriorating infrastructure, or economic decline (Chourabi et al., 2012; De Paz et al., 2016; Hui et al., 2017; Lee et al., 2014; Neirotti et al., 2014). These problems will create many challenges for the planning and the development of cities (Harrison & Donnelly, 2011). In this context, the concept of "smart city" was proposed as a solution to solve these problems by bringing several opportunities, including (Harrison & Donnelly, 2011; Kitchin, 2014; Luque et al., 2014; Neirotti et al., 2014):

- Reduce resource consumption, notably energy, water, and CO_2 emissions.
- Improve the use of existing infrastructure capacity.
- Improve the quality of life.
- Make new services available to citizens.
- Improve the city's security level.
- Predict natural disasters.
- Provide better visibility of traffic/infrastructure issues.

Hence, the concept of smart city is embedded in the sustainable development of cities (Harrison & Donnelly, 2011). Table 1 summarizes the contribution of smart city in the different areas. These areas cover different aspects of a city from technology to governance.

The focus of this chapter will be on the use of technology that plays an important role in the different aforementioned areas. As stated, IoT and AI are key technologies for the development of smart cities. So, it becomes interesting to know in more details the roles of these two technologies (i.e., AI and IoT) in the development of smart cities.

Research Methodology

In this research, we adopted a systematic literature review (SLR) approach to answer the research question. SLR is considered as "a tool for understanding state-of-the art research in fields related to a technology" (Moreira Nascimento et al., 2018, p. 2). This methodology is also considered as the most used for synthesizing knowledge since it is based on a rigorous and transparent process to identify studies (Beaudry, 2011). In addition, it allows identifying critical knowledge gaps by highlighting the discrepancy between what is currently known, what needs to be known, and what motivates other researchers to close that gap (Webster & Watson, 2002). Then, it can help to create a foundation for advancing knowledge (Moreira Nascimento et al., 2018; Webster & Watson, 2002). Finally, it helps to limit bias, reduce chance effects, enhance the legitimacy and authority of the ensuing evidence, and provide more reliable results upon which to draw conclusions and make decisions. For this, we chose to adopt this research methodology to answer our research question: what are the opportunities and the challenges that cities may face when adopting AI and IoT technologies?

Table 1 Opportunities of smart city

Area	Roles	Sources
Data management	Collect and analyze data in real time; process and anticipate data in real time; improve the interoperability of data	Hashem et al. (2016), Kitchin (2014), Tang et al. (2015), Vanolo (2014)
Transport and mobility	Ensure intelligent transport and improve traffic safety; reduce congestion, noise, and air pollution; optimize logistics in urban areas; provide intelligent parking	Arroub, Zahi, Sabir, and Sadik (2016), Caragliu, Del Bo, and Nijkamp (2011), Dirks and Keeling (2009), Djahel, Doolan, Muntean, and Murphy (2015), O'grady and O'hare (2012), Tiwari and Jain (2014)
Healthcare	Improve health sector by developing smart machines able to propose an advanced analysis to predict disease; provide new remote health services; offer new services to control citizens' health remotely	Atzori, Iera, and Morabito (2010), Dirks and Keeling (2009), Nam and Pardo (2011), Solanas et al. (2014)
Security	Strengthen security and protect the privacy of citizens; detect fraud and crime; strengthen cybersecurity; control and monitor the different urban areas	Canton (2011), Castelli, Sormani, Trujillo, and Popovič (2017), Giyenko and Im Cho (2016), Meana-Llorián, García, G-Bustelo, Lovelle, and Garcia-Fernandez (2017), Ramchurn, Vytelingum, Rogers, and Jennings (2012), Shah and Mishra (2016), Tiwari and Jain (2014)
Economy	Enrich economic and improve productivity; increase investment and innovation level	Caragliu et al. (2011), Giffinger, Fertner, Kramar, and Meijers (2007), Yigitcanlar and Lee (2014)
Education and culture	Improve education policy and personalize education; create new opportunities for students and teachers to use new technologies; promote cultural events and motivate citizen participation in the different cultural events	Caragliu et al. (2011), Dirks and Keeling (2009), Khatoun and Zeadally (2016)
Society	Ensure social integration and improve citizen participation; reduce the poverty level and create new jobs	Yigitcanlar and Lee (2014)
Services	Facilitate the accessibility of several services; improve the quality and create new intelligent services	Patti and Acquaviva (2016), Ramirez et al. (2017), Urbieta, González-Beltrán, Mokhtar, Hossain, and Capra (2017)
Environment urban	Reduce pollution and detect natural disasters; managing natural resources; protect environment and improve surveillance; improving energy efficiency	Caragliu et al. (2011), Li, Yao, Shao, and Wang (2014), Nam & Pardo (2011), Nigon et al. (2016), Rathore, Ahmad, Paul, and Rho (2016), Tiwari and Jain (2014)

(continued)

Table 1 (continued)

Area	Roles	Sources
Public administration and governance	Promote public administration by new intelligent technologies; ensure transparency in government activities; strengthen citizen's participation in political life	Caragliu et al. (2011), Dirks and Keeling (2009), Pereira, Macadar, Luciano, and Testa (2017), Schedler, Guenduez, and Frischknecht (2017)

Definition of Review Scope

In order to define the scope of this literature review, we chose to refer to an established taxonomy presented by Cooper (1988), including six characteristics for literature review: focus, goal, organization, perspective, audience, and coverage.

(a) Focus: It represents the central area of interest to the reviewer.
(b) Goal: It is related to what the author hopes the review will fulfill.
(c) Organization: It represents how literature will be organized. The literature review could be organized by: chronological, concepts, methodology, etc.
(d) Perspective: It represents the point of view of the reviewer in discussing the literature.
(e) Audience: It concerns the groups of people (such as researchers, practitioners, policy makers, general public, etc.) whom the review is addressed.
(f) Coverage: It regards how the reviewer searches the literature and how he makes decisions about the suitability and quality of documents.

The following table summarizes our choices, regarding the cooper's taxonomy about the review scope (Cooper, 1988) (Table 2).

Strategy of the Literature Review

As it was mentioned by Webster and Watson (2002), three steps are particularly important when doing a literature review to select and synthesize the existing knowledge:

1. Define the inclusion and exclusion criteria.
2. Define a strategy to locate and identify the studies.
3. Define a strategy to extract knowledge.

Inclusion and Exclusion Criteria

Four criteria were adopted to select the potential studies. To be included in our literature review, a document must:

Table 2 Cooper's taxonomy applied to our study

Characteristic	Cooper's options	Our choice
Focus	Type of papers involved (methodological, theoretical, practices, applications, outcomes)	All types of paper
Goal	Integration, criticism, research problem	Research problem
Organization	Chronological, conceptual, methodological	Chronological first, conceptual after
Perspective	Neutral, espousal of a position	Neutral
Audience	Groups of people whom the review is addressed	Specialized scholars and decisions-makers
Coverage	Exhaustive, with selective citation, representative, central, pivotal	Representative

1. Propose a conceptual and/or operational definition of the concept of smart city.
2. Focus on IA and IoT use in smart cities context.
3. Be a document published between 1990 and 2017. The choice of 1990 as a starting date is justified by Breux and Diaz (2017) who proved that 1990 represents the emergence date of "smart cities" concept.
4. Include the following types of documents: journal or conference paper, books, and reports. However, memories, theses, and editorials were not retained. The choice to exclude memories and theses is recommended by Beaudry (2011) who indicated that all important scientific contributions in these types of documents should be published in a scientific paper.

Data Sources and Studies Selection

To locate studies, two stages were adopted to look and select articles included in our literature review. Firstly, we preceded by an electronic search by using multiple keywords (see Table 3) in several multidisciplinary databases recommended by a librarian expert at our university: ABI/INFORM Global of Proquest, Academic Search Premier (ASP) of EBSCO, ScienceDirect of Elsevier, and Web of Science. Then, we performed a manual search in Google Scholar. Our search query was based on the thesauruses of IoT and AI generated by the different databases consulted, which do not necessarily give all the keywords of these concepts. So, we recognize that other complementary keywords should have been used to look for broader IoT and AI related studies on smart cities. Such keywords can be, for example: 5G networks, or wearable devices among others.

From this search, we identified 5430 potential studies for our literature review (i.e., 2221 studies presented in Web of Science, 1583 studies presented in ABI/INFORM Global, 647 studies presented in Academic Search Premier, 320 studies presented in ScienceDirect, and 659 studies selected from Google Scholar). The

Table 3 Search queries

Search query n°1	((**“**Artificial Intelligence**”** **OR** **“**Machine Learning**”** **OR** **“**Deep Learning**”** **OR** **“**Robots**”** **OR** **“**Avatars**”** **OR** **“**Chatbots” **OR** “Neural Network” **OR** “Fuzzy Logic” **OR** “Learning Algorithm” **OR** “Expert Systems” **OR** “Cognitive Computing” **OR** “Genetic Algorithm” **OR** “Evolutionary Algorithm” **OR** “Expert Systems” **OR** “Evolutionary Algorithm” **OR** “Expert Systems” **OR** “Time Series Forecasting” **OR** “Genetic Programming” **OR** “Symbolic Regression”) **AND** (**“**Smart Cit*”** **OR** **“**Future Cit*”** **OR** **“**Digital Cit*”** **OR** **“**Intelligent Cit*”** **OR** **“**Sustainable Cit*” **OR** “Knowledge Cit*” **OR** “Ubiquitous Cit*” **OR** “Interconnected Cit*” **OR** “Cyber Cit*”))
Search query n°2	((“internet of things” **OR** “future internet” **OR** “M2M”) **AND** (**“**smart Cit*”** **OR** **“**future Cit*”** **OR** **“**digital Cit*”** **OR** **“**intelligent Cit*”** **OR** **“**sustainable Cit*” **OR** “knowledge Cit*” **OR** “ubiquitous Cit*” **OR** “interconnected Cit*” **OR** “cyber Cit*”))

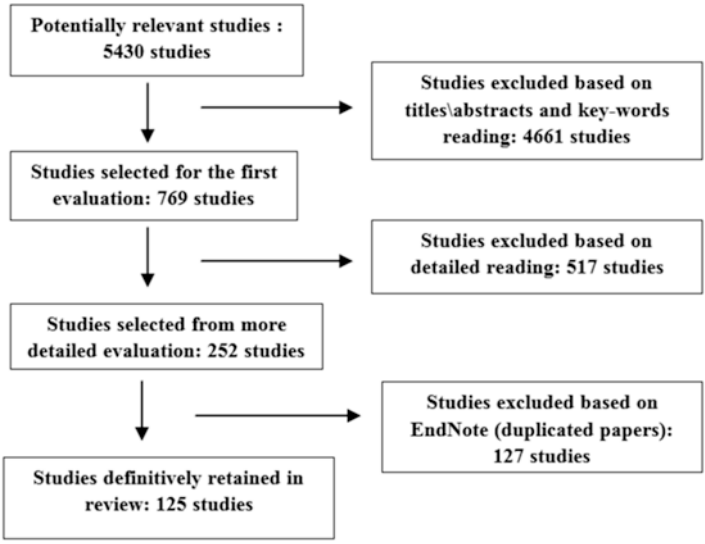

Fig. 1 The flow diagram of the literature review

identified articles (i.e., 5430 papers) were subject to a double screening (see Fig. 1). A first sorting consisted to verify the inclusion and the exclusion criteria from reading the title, the abstract, the keywords, and the introduction of each study. 769 potential articles remained after the first sorting for a thorough analysis. Then, we made a detailed reading of the papers to only retain relevant papers. We eliminated 517 documents and we kept 252 studies. Finally, we removed duplicated papers by eliminating 127 documents and only 125 studies were definitively retained in this literature review as depicted in Table 4.

Table 4 Synthesis of the identified documents

Database	First sort	Second sort	Third sort
Web of Science	120 (15%)	34 (13%)	24 (20%)
ScienceDirect	97 (13%)	25 (10%)	13 (11%)
ABI/INFORM Global	147 (19%)	46 (18%)	23 (19%)
Academic Search Premier	160 (21%)	37 (15%)	17 (14%)
Google Scholar	245 (32%)	110 (44%)	48 (36%)
Total	*769*	*252*	*125*

Knowledge Extraction Strategy

To extract knowledge, we created an Excel sheet that contained each article's reference (i.e., title, authors, year), research type (i.e., qualitative, quantitative, mixed, literature review, survey), scientific contribution (i.e., practical or theoretical contribution), technology used in a smart city, and the summary of each research topic.

Descriptive Analysis of the Included Studies

The distributions of the included studies per type (see Fig. 2) show that the articles represent 92% of included studies, 5% are books, and 3% are reports. The distribution of the included studies per research type (see Fig. 3) shows that the most evoked research type was a conceptual research (with 43% of included publications), 41% were case studies, 8% were literature reviews, 5% were quantitative researches, and 3% were qualitative researches. We can see that the number of quantitative and qualitative studies is low and represents a challenge for future research, since this type of research proposes exact studies based on evidence data (Hunt & Lavoie, 2011). Moreover, the low number of literature reviews reflects an immature literature that needs to be studied (Taylor Buck & While, 2017).

The distribution of research type per year shows that since 2013 there has been a shift in focus toward literature reviews (see Fig. 4) since there are more and more research studies on smart cities.

The distribution of studies per publication year shows that the rate of published studies increased remarkably since 2010 to reach an average of 15 articles per year for the period 2010–2017 (see Fig. 5), which confirms that a large amount of literature around this studied area has been published in the last 10 years (Ishida, 2017).

Findings

Nowadays, the concept of smart city represents a catchphrase that draws increased attention among research institutes, universities, governments, policymakers, and ICT companies (Bibri & Krogstie, 2017; Cocchia, 2014; Dohler, Vilajosana,

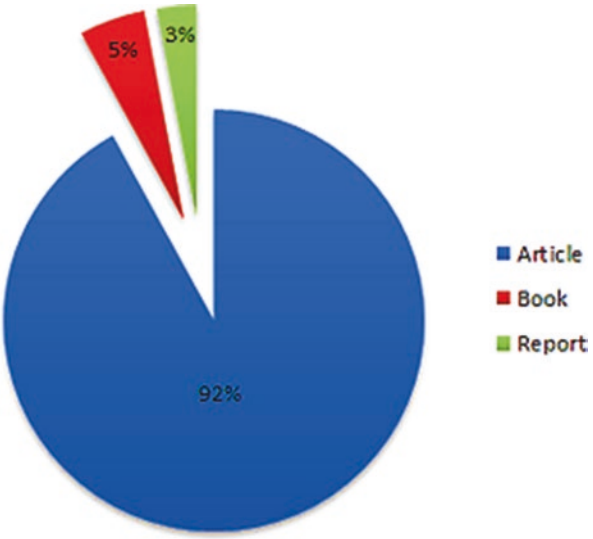

Fig. 2 The distribution of studies per document type

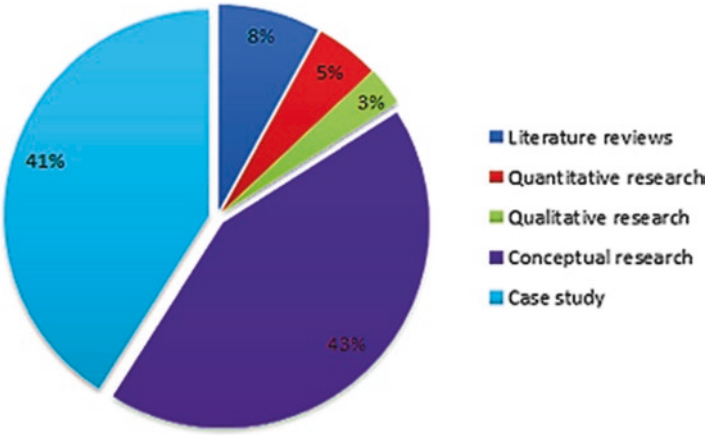

Fig. 3 The distribution of studies per research type

Vilajosana, & Llosa, 2011; Zhuhadar, Thrasher, Marklin, & de Pablos, 2017). It represents a profoundly interdisciplinary field, which makes the concept of smart cities rather vague and complicated (Bibri & Krogstie, 2017; Hause & Hummell, 2016; Hollands, 2008). This literature review shows that there are different views regarding the complexity of this concept. Several authors (e.g., (Bibri & Krogstie, 2017; Gupta & Hall, 2017; Harrison & Donnelly, 2011; Lee et al., 2014; Thrift, 2014)) mention that the complexity of "smart city" refers to the complexity of the term "smartness" that can have multiple meanings such as: safe, connected,

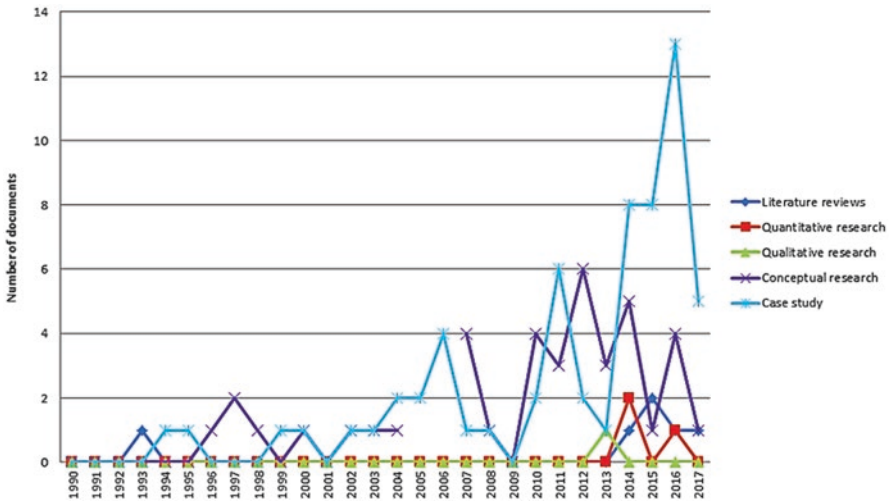

Fig. 4 The distribution of studies per year

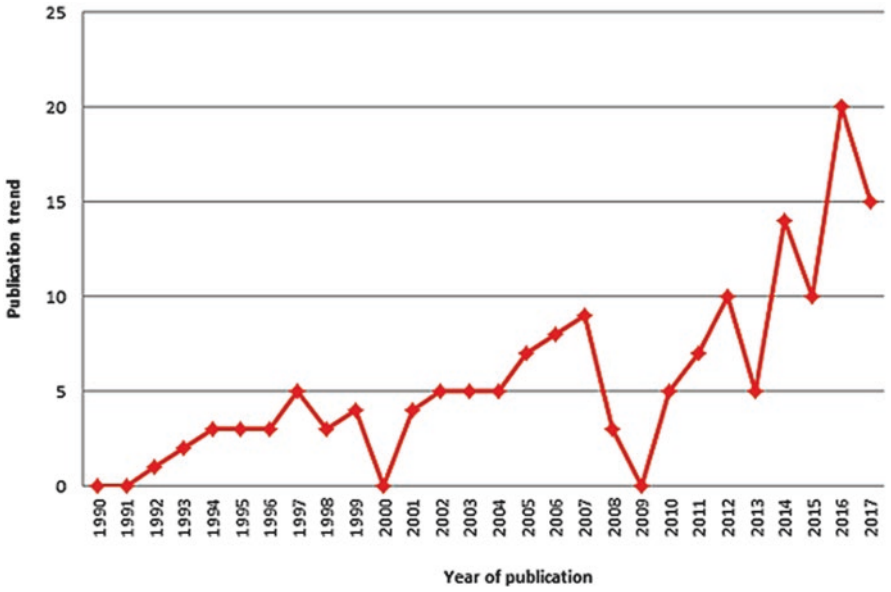

Fig. 5 Publication trend (1990–2017)

intelligent, green, sustainable, etc. In addition, there is not a standard measure to evaluate the smartness level of a smart city (Albino, Berardi, & Dangelico, 2015; Balakrishna, 2012; Jucevičius & Liugailaitė-Radzvickienė, 2014). However, the analysis of the literature shows that there are essentially five levels to characterize

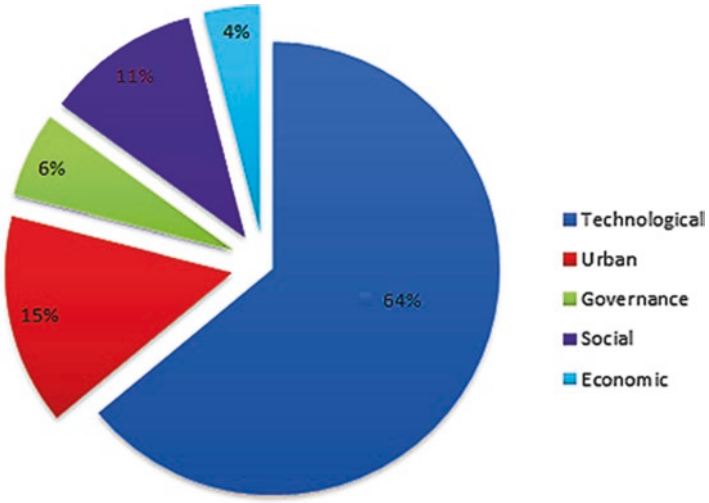

Fig. 6 Bases for assessing the level of smartness of a smart city

the smartness level of a smart city (see Fig. 6): (1) technological level, (2) social level, (3) governmental level, (4) economic level, and (5) urban level. According to our analysis of the literature, we identified that the most cited factor influencing the smartness level of a smart city is the technological level (with 64% of the studies referred to this level to measure the smartness of smart cities). Then, 15% of the studies refer to the urban level, 11% of studies focus on the social level, 6% on governance development, and 4% on economic development.

In addition, the examination of the literature brought out four typologies that have been proposed to conceptualize a smart city:

1. The first typology (Anthopoulos, 2015; Arroub et al., 2016; Balakrishna, 2012; Chamoso & Prieta Pintado, 2015; Giyenko & Im Cho, 2016; Gubbi, Buyya, Marusic, & Palaniswami, 2013; Hui et al., 2017; Jucevičius & Liugailaitė-Radzvickienė, 2014; Mathur & Modani, 2016; Nigon et al., 2016; Patti & Acquaviva, 2016; Sakhardande, Hanagal, & Kulkarni, 2016; Srivastava, Bisht, & Narayan, 2017; Talari et al., 2017; Vakali, Anthopoulos, & Krco, 2014; Vattapparamban, Güvenç, Yurekli, Akkaya, & Uluağaç, 2016) conceptualizes a smart city as a modern city that uses cutting-edge technologies, such as: IoT, AI, and cloud computing to provide an intelligent infrastructure to solve several urban problems. These cutting-edge technologies are defined as new technologies used to perform new functions or greatly enhance functions compared to commonly used technologies (Struecker, Raschzok, & Sauer, 2014).
2. The second typology (Dohler et al., 2011; Hollands, 2008; Lee et al., 2014; Lombardi, Giordano, Farouh, & Wael, 2011; Neirotti et al., 2014; Ojo, Curry, & Janowski, 2015; Pereira et al., 2017) conceptualizes a smart city as a system based on information and communication technologies (ICT) to improve provided services in order to increase the quality of life of citizens.

3. The third typology (Caragliu et al., 2011; Coe, Paquet, & Roy, 2001; Dwivedi & Bharti, 2010) defines a smart city as an entity based on smart governance that aims to develop intelligent strategies to solve social problems.
4. The fourth typology (Aoun, 2013; Roberts & Sykes, 1999) describes a smart city as an entity based on a smart community that aims to optimize environmental resources.

The descriptive results of our analysis (see Fig. 7) show that the literature on smart cities gives a particular importance to the first typology related to the use of cutting-edge technologies. In fact, about 76% of the studies focus on cutting-edge technologies (specifically, 57% of the studies focus on AI, 43% focus on IoT, and 3% focus on cloud). However, 15% of the studies focus on ICT, 5% of the studies focus on governance, and finally 4% of the studies focus on citizens and community. As presented in Fig. 8, the number of publications focusing on cutting-edge

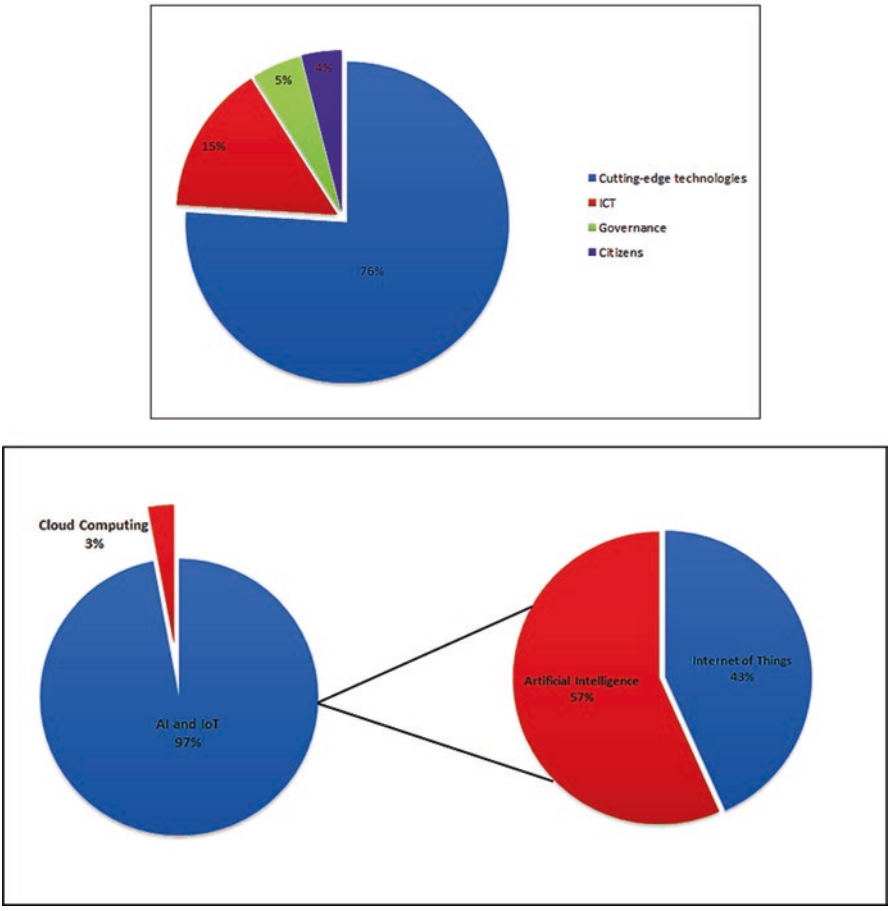

Fig. 7 Typologies of a smart city

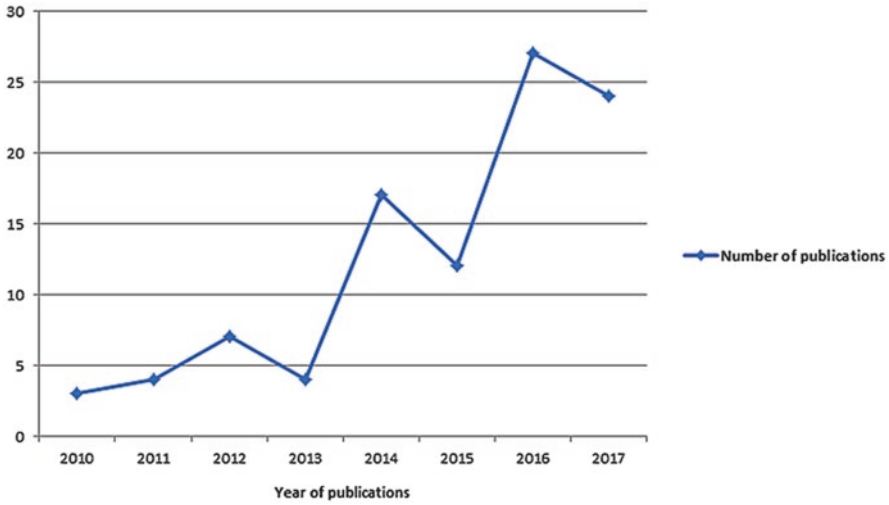

Fig. 8 Publication trend of cutting-edge technologies

technologies is increasing in recent years, which shows the interest of researchers to study this area.

Based on these different results, the next section examines the role of IoT and AI in smart cities.

Opportunities of AI and IoT in Smart Cities

After identifying the cutting-edge technologies that make a city smart, we discuss in this section the roles of IoT and AI in the development of smart cities, and we identify their opportunities and the challenges that have been depicted to ensure a responsible use of these technologies.

The Internet of Things in Smart Cities

What Is the Internet of Things?

Even though the term "Internet of Things" was coined in 1999 (Ashton, 2009), the technologies that enable IoT such as sensor networks existed since the 1990s. Due to the technological advances (i.e., the advances of sensors and cloud technologies, processing and storage capabilities, decreased sensors production cost, etc.), the concept of IoT knew a great growth in the last decade (Borgia, 2014) and it "will

transform the real-world objects into intelligent virtual objects" (Perera, Zaslavsky, Christen, & Georgakopoulos, 2014, p. 164). As we can observe, IoT is primarily driven by technological advances but not by applications or user needs (Madakam, Ramaswamy, & Tripathi, 2015). By definition, IoT allows people and things to be connected anytime, in anyplace, with anything, and by anyone, ideally using any path/network and any service (Borgia, 2014). As (Koreshoff, Robertson, & Leong, 2013) states, the technology of IoT refers "to a broad vision whereby things such as everyday objects, places and environments are interconnected with one another via the Internet" (Koreshoff et al., 2013, p.335).

Our analysis of the literature shows that there are several definitions of IoT. These definitions can be grouped into three streams. The first stream of definitions characterizes IoT as an invisible framework to connect a plethora of digital devices with the Internet (Madakam et al., 2015; Mehmood et al., 2017; Ramirez et al., 2017; Talari et al., 2017). The second stream of definitions characterizes IoT as an evolution of the Internet that uses new strategies to ensure the connectivity between different objects (Hui et al., 2017; Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014; Zhuhadar et al., 2017). The third stream of definitions describes IoT as a cutting-edge technology applied on a large scale of urban areas to collect, share, and communicate data between all objects (Gubbi et al., 2013; Hashem et al., 2016; Papadokostaki et al., 2017).

The Role of IoT in Smart Cities

According to our analysis of the literature, we identified that IoT technology is expected to substantially support the sustainable development of smart cities (Vlacheas et al., 2013). It can ensure the connection between geospatial objects (Hui et al., 2017), increase security (Qela & Mouftah, 2012), improve services (Vattapparamban et al., 2016), or optimize natural resources (Gupta & Hall, 2017). The main roles of IoT identified from our analysis of the literature in smart cities are:

1. *Ensure the connectivity between all objects:* Gubbi et al. (2013), Madakam et al. (2015), Ramirez et al. (2017), Sarin (2016), Talari et al. (2017) show that the technology of IoT is used primarily to ensure the ubiquitous connectivity between different objects in the different urban areas.
2. *Real-time data processing:* IoT allows to collect a large amount of data that can be analyzed, stored, and shared (Balakrishna, 2012; Hashem et al., 2016; Tang et al., 2015; Trilles, Belmonte, Schade, & Huerta, 2017). Papadokostaki et al. (2017) illustrated that: "Handling Big Data in real-time represents the Era of IoT" (Papadokostaki et al., 2017, p. 1).
3. *Increasing security:* IoT provides solutions to monitor the movements of people and objects in different areas of a city in order to improve the security level (Vattapparamban et al., 2016; Zanella et al., 2014). However, Su, Li, and Fu (2011) pointed that this role can offense the privacy of people.

4. *Supply management of natural resources:* IoT helps to ensure a proper supply management of natural resources (such as water, energy, etc.) to better control these resources, reduce costs, and improve the economy (Petrolo, Loscri, & Mitton, 2014).
5. *Improve and optimize public services*: Bhatt et al. (2017) and Petrolo et al. (2014) showed that IoT refers to the world of smart connected objects and devices, which allows to improve and facilitate the accessibility of services and create several new intelligent and personalized services.

Examples of Application Areas of IoT in Smart Cities

We looked only at the applications from the reviewed papers. We found five application areas of IoT in smart cities (see Fig. 9): smart home, smart transport, smart healthcare, urban environment, and industry.

Smart Home

It represents the most applied areas of IoT (with 33% of the studies). The technology of IoT is used in smart homes to: improve the security and the surveillance level, provide control of the temperature, detect risks, control all elements in the house, improve convenience and the comfort of the inhabitants, and ensure connectivity between all houses via a neighborhood network in order create a smart community (Bregman, 2010; Darianian & Michael, 2008; Gubbi et al., 2013; Hui et al., 2017; Jaradat, Jarrah, Bousselham, Jararweh, & Al-Ayyoub, 2015; Jin, Gubbi, Marusic, & Palaniswami, 2014; Skouby & Lynggaard, 2014; Su et al., 2011; Zanella et al., 2014).

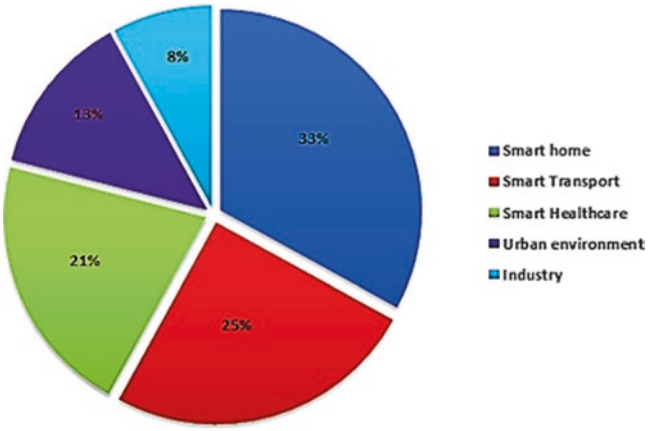

Fig. 9 Distribution of studies per areas of IoT application in smart city

Smart Transport

It represents the second most applied areas of IoT (with 25% of the studies). This technology is used in transport area to: create new routing services, ensure an intelligent tracking of vehicles, provide smart parking (e.g., IoT can track car arrival and departure times, identify empty parking spaces to avoid traffic jams), improve security level through the use of road sensors or RFID (Behrendt, 2016; Bing, Fu, Zhuo, & Yanlei, 2011; Hause & Hummell, 2016; Masek et al., 2016; Ricquebourg et al., 2006), control traffic and ensure a smart display on road conditions to reduce pollution, optimize mobility of people, and save lives (Tsaramirsis, Karamitsos, & Apostolopoulos, 2016).

Smart Healthcare

It represents the third most applied area of IoT in smart cities (with 21% of the studies). This technology allows remotely monitoring patients (24/7) (Su et al., 2011), connect doctors, patients, and nurses via smart device, and each entity can roam without any restriction, collect data about patients' states in real time, locate patients and improve their safety, ensure management of medical emergencies, and management of transfusion information management and real-time health (Boulos & Al-Shorbaji, 2014; Islam, Kwak, Kabir, Hossain, & Kwak, 2015; Su et al., 2011).

Urban Environment

It is the fourth most applied area of IoT (with 13% of studies). Several authors (e.g., (Rathore et al., 2016; Sakhardande et al., 2016; Schaffers et al., 2011)) mentioned that IoT technology can be used to control natural resource systems, temperature, air quality, environment, humidity, weather, rain, carbon dioxide level and harmful gases, noise, and waste management to improve the urban environment.

Industry

It is the last application area of IoT in smart cities context (with 8% of the studies). It allows automating tasks, improving logistics, controlling breakdowns, and providing surveillance in different factories (Sundmaeker, Guillemin, Friess, & Woelfflé, 2010; Uckelmann, Harrison, & Michahelles, 2011).

In short, our analysis of the literature showed the importance of IoT that can be transparently and seamlessly incorporated in a large number of heterogeneous systems (Zanella et al., 2014), and it can play a crucial role in all areas of smart cities. However, several ethical, social, and technical problems can be generated by this technology. Section "Challenges of IA and IoT in Smart Cities" describes the challenges of IoT in smart cities context.

Artificial Intelligence (AI) in Smart Cities

AI is not a new field of research and application. Its beginning is dated to the 1950s (Kurzweil, 2000; Simon, 1996; Turing, 1996), and it began as an inquiry into the nature of intelligence. This technology acquires today a great importance in all areas of smart cities (Nakashima, Aghajan, & Augusto, 2009; Nigon et al., 2016). To better understand the importance of this technology, we will discuss in this section the roles and the applications area of AI in smart cities.

What Is Artificial Intelligence?

Through our analysis of the literature, we have identified two streams of definitions that have been proposed to describe the concept of artificial intelligence: The first stream (Cath, Wachter, Mittelstadt, Taddeo, & Floridi, 2018; Coppin, 2004; Yudkowsky, 2008) characterizes the artificial intelligence as an imitation of human intelligence and human abilities in order to build intelligent machines. The second stream (Aimé, Charlet, Maillet, & Belin, 2015; Lauterbach & Bonim, 2016; Steels, 1993) conceptualizes AI as a simulation between human intelligence and machine abilities in order to solve complex problems. In this context, David et al. (1998) defined AI as the science of building intelligent agents to perform tasks like a human being and reason as a human. In the same way, Coppin (2004) shows that AI is a new area to "involve using methods based on the intelligent behavior of humans to solve complex problems" (Coppin, 2004, p. 31). Despite the diversity of the definitions of artificial intelligence, there is no single universally accepted definition of AI (Cook, Augusto, & Jakkula, 2009). But, we can say that this technology represents a subpart of computer science, concerned with how to give computers the sophistication to act intelligently without being explicitly programmed by using several areas of study and technologies such as voice recognition, image recognition, and natural language processing (Cao et al., 2016; Caragliu et al., 2011).

The Role of AI in Smart Cities

According to our analysis of the literature, we have identified several roles that AI plays in smart cities:

(a) *Ensure an intelligent monitoring:* AI can be used to control and analyze data collected from different sensors to optimize operations (Augusto, Nakashima, & Aghajan, 2010). It can be used, for example, to monitor physical infrastructure or natural resources.
(b) *Ensure an intelligent use of natural resources:* AI allows, for example, to monitor the lighting system by determining the lighting times based on the light levels according to the traffic, which can help to increase energy efficiency,

reduce energy costs, and improve sustainability (Hui et al., 2017; Lauterbach & Bonim, 2016).

(c) *Improve industrial automation:* The use of AI in the form of robots can play an important role in manufacturing industry (Ganascia, 1993) where robots can perform difficult tasks. In addition, AI can be used to detect customer needs, which improve the product quality of a company and increase its economic level (O'Leary, Kuokka, & Plant, 1997).

(d) *Improve the security level:* AI helps to improve the security level in different areas of smart cities. For example, AI can help to predict crimes and improve security in different urban areas (Zhang et al., 2014).

(e) *Improve the interaction with citizens:* The use of different forms of AI as virtual assistants will improve the interactions with citizens (Mathur & Modani, 2016). This technology is already used in different messaging applications such as Messenger, Slack, or WeChat (Shawar & Atwell, 2007).

(f) *Ensure spatiotemporal reasoning:* Augusto et al. (2010) mentioned that AI technology can ensure a spatiotemporal reasoning. For example, a heating system can detect whether a human is present in the room or not to react appropriately and add the temperature to a comfortable level, thereby improving the economy and comfort of citizens.

(g) *Dealing with big data:* AI helps to model, analyze, and transform a large amount of data into reliable information (Cao et al., 2016; Nigon et al., 2016; Pérez et al., 2014), which can improve the quality of the decision-making processes.

(h) *Anticipate needs and adapt services:* AI helps to anticipate need which makes it possible to personalize different services (Ramchurn et al., 2012).

(i) *Ensure an intelligent network:* Castelli et al. (2017), Zhuhadar et al. (2017) mention that AI allows to model, analyze, and predict data in real time without any human intervention.

(j) *Ensure a behavioral modeling:* AI can be used to guarantee a behavioral modeling of data in real time to improve, for example, cybersecurity or increase environmental security (Augusto et al., 2010; Skouby & Lynggaard, 2014).

Applications Areas of AI in Smart Cities

We looked only at the applications from the reviewed papers. As depicted in Fig. 10, the most used area of IA is healthcare (with 26% of studies), then, smart home (with 16% of studies), government (with 12% of studies), learning (with 10% of studies), and security (10% with studies).

1. **Smart Health:** The use of AI in healthcare provides several opportunities to solve real-world healthcare problems (Acampora, Cook, Rashidi, & Vasilakos, 2013; Baxt, 1995; Desouza, 2001; Koh & Tan, 2011; Szolovits, 1982; Zang, Zhang, Di, & Zhu, 2015). For example, it can ensure a correct diagnosis, a precise analysis, an exact prediction of diseases (as cardiovascular disease, cardiac events, etc.), and an efficient treatment of hospital data (Patel et al., 2009;

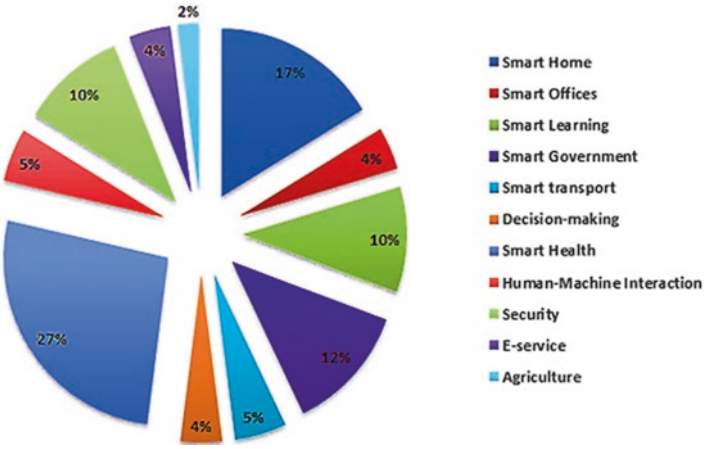

Fig. 10 Distribution of AI application areas in smart city

Speight, Elliott, Jullien, Downer, & Zakzrewska, 1995). This technology can also help to determine an intelligent analysis of complex medical data to provide an effective prediction of diseases (Crawford et al., 2000; Grossi, 2006;Patel et al., 2009; Speight et al., 1995), to identify and predict the chemical carcinogens (Lette et al., 1994; Rosenkranz, Mitchell, & Klopman, 1985), and to improve data analysis in different clinical scenarios (Patel et al., 2009; Speight et al., 1995).

2. **Smart Transport:** AI is used in transportation systems to solve several problems and ensure an intelligent transport (Dias, Bellalta, & Oechsner, 2015; Liebig, Piatkowski, Bockermann, & Morik, 2014; Tsaramirsis et al., 2016). For example, AI is used to: develop autonomous cars (Giyenko & Im Cho, 2016), predict traffic risks and congestion zones (Dias et al., 2015; Mathur & Modani, 2016), ensure an intelligent parking management, develop intelligent solutions to reduce accidents, etc.
3. **Smart Home:** The use of IA makes homes smarter and able to anticipate our actions and our preferences (Augusto, 2007; Augusto et al., 2010; Cook et al., 2003; Li, Da-You, & Bo, 2004; Qela & Mouftah, 2012; Ricquebourg et al., 2006; Robles & Kim, 2010; Skouby & Lynggaard, 2014; Srivastava et al., 2017). This technology allows, for example, to inform a resident when it is time to take its medication, alert the hospital if the resident has fallen, closing the water, or turning off the oven, etc. Hence, AI will render homes intelligent and able to adapt to the needs of the habitants (Cook et al., 2003).
4. **Smart Government:** AI is used by governments to provide intelligent and personalized services in order to ensure a smart public administration (Adadi, Berrada, Chenouni, & Bounabat, 2015; Chun, 2007; Coe et al., 2001; Harsh & Ichalkaranje, 2015; Pereira et al., 2017; Schedler et al., 2017). The use of AI in governments will improve, for example, participation, transparency, efficiency,

accountability, and inclusion to ensure an effective government (Mahapatra, Sharma, Trivedi, & Aman, 2012).

5. **Smart Learning:** AI integrated into different education systems will help to improve the education level, make classrooms smart, support teachers, and students with the use of virtual assistants that can play the role of "tutor" for students, automate the different administrative tasks, and provide personalized help (Heller, Proctor, Mah, Jewell, & Cheung, 2005; McArthur, Lewis, & Bishary, 2005; Mikulecký, 2012; Holmes et al., 2019; Shi et al., 2003; Xie, Shi, Xu, & Xie, 2001).
6. **Security**: The use of AI can improve the security level in different area of smart cities. This technology integrated in different objects can provide capabilities to monitor urban areas through the analysis of movements and the prediction of crimes (Cao et al., 2016; Castelli et al., 2017; Dragomir, 2017; Ramchurn et al., 2012), ensure surveillance of device networks to detect cyberattacks and to improve cybersecurity (Sharbaf, 2018), or secure physical sites such as parks or museums.
7. **Smart Offices:** AI is integrated in different devices such as: robots, cameras, or sensors to make these devices able to support office activities and help in carrying out daily tasks to improve quality of work (Augusto et al., 2010; Mikulecký, 2012; Mizoguchi, Nishiyama, Ohwada, & Hiraishi, 1999).
8. **Human-Machine Interaction:** The use of AI in the form of virtual assistants allows to improve human–machine interactions (Hill, Ford, & Farreras, 2015; Mahapatra et al., 2012) through the discussions with humans in real-time to answer their question, Cleverbot (Hill et al., 2015) and ELIZA (Natale, 2019).
9. **Agriculture:** The deployment of robotics in agriculture area ensures soil preparation, seeding, fertilization, and harvesting (Hollingum, 1999). In addition, the use of AI algorithms can ensure the production of the best combination of soils for better plant management, or the detection of plant diseases, plant protection and control (Murase, 2000). In addition, the use of AI in the form of sensor-equipped drones enable the immediate detection of theft, risks, and anomalies through the collection and analysis of data in real time (Aitkenhead, Dalgetty, Mullins, McDonald, & Strachan, 2003).
10. **Decision-making:** With the emergence of big data and open data, AI can be considered as a helpful tool in decision-making. It can improve the effectiveness of decision-making processes and reduces error rates (Cao et al., 2016; Cortés, Sànchez-Marrè, Ceccaroni, R-Roda, & Poch, 2000) by analyzing data and simulating the future without any human intervention.
11. **E-service:** E-services refer to the use of AI to develop personalized services and creating intelligent services based on intelligent interactions (Lu, Ruan, & Zhang, 2007).

Despite the importance of AI and IoT and the opportunities that they bring to societies, cities may face many challenges related to AI and IoT. These challenges will be discussed in the next section.

Challenges of IA and IoT in Smart Cities

Challenges of AI in Smart Cities

According to our analysis of the literature, we identified several social, legal, and ethical challenges related to AI (Bostrom, 2017; Hawking, Russell, Tegmark, & Wilczek, 2014):

1. Social challenges: The use of AI allows to imitate human behavior and to perform several difficult tasks. However, several researchers raised the problem of unemployment where the robots will replace humans in doing certain jobs (Bostrom & Yudkowsky, 2014; Brooks et al., 1996; Coppin, 2004).
2. Legal challenges: Currently, there is no legal framework that organizes the responsibilities of AI (Bostrom, 2017; Brooks et al., 1996). For example, "will an autonomous car be responsible of an accident?" (Gurney, 2013). Thus, O'grady and O'hare (2012) found that with the emergence of artificial intelligence, robots will become the future residents of smart cities. So, "what is the status of these residents?"
3. Ethical challenges: They can be considered as one of the most challenging for cities (Bostrum, 2014; Frankish & Ramsey, 2014; Hawking et al., 2014). In fact, AI can be able to: imitate human brain, analyze human behavior (Brundage, 2015), trace people and make facial recognition (Bostrom & Yudkowsky, 2014), or even create dependency of people to AI applications (Coppin, 2004), which influence the confidentiality of human privacy and will pose several ethical questions.

Recognizing that these challenges represent a huge challenge, it is important to note that future development of AI can bring more complicated challenges. In this context, several authors (Bostrom, 2017; Bostrom & Yudkowsky, 2014; Bostrum, 2014; Frankish & Ramsey, 2014) indicated that with the next evolution of AI that will be a strong AI, we will witness several existential risks (Brundage, 2015), where Yudkowsky (Yudkowsky, 2008) illustrates that: "A powerful AI could overwhelm any human resistance" (Yudkowsky, 2008, p. 9).

Challenges of IoT in Smart Cities

Through our analysis of the literature, we have identified several challenges related to IoT (Sarin, 2016; Sundmaeker et al., 2010):

1. Ethical issues: With the increasing number of connected objects, that will be expected to reach between 26 and 50 billion globally by 2020 (Sundmaeker et al., 2010), IoT can be used to control citizens and communicate their confidential data. So, one of the crucial questions to which IoT has to answer is: "What

extent privacy is protected?" (Jin et al., 2014). For example, several confidential data can be collected by different sensors and that can be shared with other sensors or with other third parties without consent.
2. Security issues: Several authors (Mehmood et al., 2017; Vattapparamban et al., 2016) mentioned that 70% of IoT devices in a smart city were at risks of attacks due to sufficient vulnerabilities such as: free permissions or access, inadequate software protections, or weak encrypted communication protocols.
3. Epistemological and socio-technical issues: Freedom control, authority, independence, automatism, adaptability, and integrity represent major challenges of IoT (Saleh, 2017). For example, connected cars can integrate online data from other protocols that can configure data of the car, share data about the condition of the car, and could even give access of the car to third parties automatically and independently of the driver.

Conclusion

Currently, urban performances depend not only on a city's infrastructure but also increasingly on technological infrastructure. The present chapter aimed to identify the role of the key technologies (i.e., IA and IoT) for smart city development through a literature review. These technologies are used to improve urban infrastructure, optimize natural resources, ensure public safety, optimize and personalize public services, etc. But they also pose several ethical, social, technological, and legal problems different from one city to another, according to: the technological infrastructure of smart cities, economic development, priorities, political structures, legal framework, etc.

To ensure a proper use of these technologies, some governments adopted several strategies, such as: the European Union who created a "European Agency for Robotics and AI" to control the use of AI (Cath et al., 2018). In addition, the United Kingdom called for the development of new regulatory frameworks to organize the use of IA and IoT (Fiander & Blackwood, 2016). As well, the White House and the European Parliament published a report outlining their visions on how to prepare the society for the widespread use of several technologies (as, the artificial intelligence) in order to ensure a "good AI society" (Artificial Intelligence, 2016). However, these reports do not provide an overarching political vision and long-term strategy for the development of these technologies.

For this, we propose as future work, three main research avenues. First, we extend our literature review by using complementary keywords for IoT and AI to have a better overview on the studies about the use of these two technologies in smart cities. Second, through this literature review, we think that it is important to define a new integrative framework to deal with the challenges of AI and IoT in smart cities. Such framework will allow us to understand the role and the responsibility of the government and the research community in the development of IA and IoT technologies. Third, we think that it is important to develop a new model to

understand how we can get the most out of AI and IoT in order to ensure a responsible use of these technologies to be beneficial to the society.

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