A systematic review of smart cities and the internet of things as a research topic

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Abstract

This study aims to analyze the current academic literature on Smart Cities and the Internet of Things using bibliometric analysis and quantitative content analysis. It primarily consists of extracting data from the web-of-science: citations, languages, countries, most prolific authors, the most relevant works, keywords, institutions, conferences, and journals. Results confirm that the most preeminent literature on Smart Cities and the Internet of Things focuses on developed countries with a long tradition of innovation and IT research showing a similar pattern. From this analysis, limitations and opportunities for future studies are observed. A research agenda and suggestions for new theoretical questions were developed for scholars of Smart Cities and the Internet of Things.

Keywords: Systematic Review. Text mining. Smart Cities. Internet of Things. Innovation.

Revisão sistemática de cidades inteligentes e internet das coisas como tópico de pesquisa

Resumo

Este estudo tem por objetivo analisar a literatura acadêmica atual sobre cidades inteligentes (*Smart Cities*) e internet das coisas (*Internet*, utilizando análise bibliométrica e análise de conteúdo quantitativa. Essencialmente, consiste em extrair dados das bases Web of Science: citações, idiomas, países, autores e trabalhos mais relevantes, palavras-chave, instituições, conferências e periódicos. Os resultados confirmam que a literatura mais proeminente sobre cidades inteligentes (CIs) e IoT Internet das Coisas se concentrou em países avançados com longa tradição de inovação e pesquisa em tecnologia da informação (TI), mostrando um padrão similar. O estudo se inspira em percepções dessa análise e observa algumas advertências e oportunidades para futuras pesquisas. Desenvolveu-se uma agenda de pesquisa e sugestões de novas questões teóricas para pesquisadores em CIs e IoT.

Palavras-chave: Revisão sistemática. Mineração de texto. Cidades inteligentes. Internet das coisas. Inovação.

Revisión sistemática de las ciudades inteligentes e internet de las cosas como tema de investigación

Resumen

Este estudio tiene como objetivo analizar la literatura académica actual sobre ciudades Inteligentes (*smart cities*) e internet de las cosas, utilizando análisis bibliométrico y análisis de contenido cuantitativo. Esencialmente, consiste en extraer datos de las bases Web of Science: citas, idiomas, países, autores y trabajos más relevantes, palabras clave, instituciones, conferencias y periódicos. Los resultados confirman que la literatura más prominente sobre ciudades inteligentes e internet de las cosas se concentró en países avanzados con una larga tradición de innovación e investigación en TI, mostrando un patrón similar. El trabajo se inspira en percepciones de este análisis y observa algunas advertencias y oportunidades para futuras investigaciones. Se desarrolló una agenda de investigación y sugerencias de nuevas cuestiones teóricas para investigadores de ciudades inteligentes e internet de las cosas.

Palabras clave: Revisión sistemática. Minería de textos. Ciudades inteligentes. Internet de las cosas. Innovación.

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INTRODUCTION

Digital technologies are transforming the way we live. Examples are cloud computing, Internet of Things (IoT), smart cities, advanced robotics, big data, artificial intelligence (AI), three-dimensional printing, virtual reality, biotechnology, broadband internet, and wireless mobility. Broadband internet, wireless mobility, the digitization of information and the globalization of business are nothing new and offer new possibilities. However, advances in information technology are altering the dynamics of economic growth and the way cities and how they engage with citizens.

This paper aims to identify the current state of this academic literature regarding Smart Cities and Internet of Things, and thus identify and analyze its knowledge base by using bibliometric analysis and quantitative content analysis.

In previous studies, bibliometric analyses method has been conducted in different areas (DURISIN and PUZONE, 2009; DI STEFANO, PETERAF and VERONA, 2010). Regarding specifically on smart cities research includes the work of De Jong, Joss, Schraven et al. (2015). This work reflecting recent developments, identifies new categories as sustainable cities; green cities; digital cities; smart cities; intelligent cities; information cities; knowledge cities; resilient cities; eco-cities; low carbon cities; liveable cities; and even combinations, such as 'low carbon eco-cities' and 'ubiquitous eco-cities', as well as those of Bayulken and Huisingh (2015). In another recent work Ojo, Dzhusupova and Curry (2016) use the bibliometric methodology to discuss the phenomenon in smart cities and an emerging understanding of the smart city concept. Also, Mondal and Zulfi (2017) discussed the Internet of Things (IoT) and the Wireless Sensor Network (WSN) are becoming a reality, their interconnections for smart devices are increasing. Smart devices are integrated with sensors and embedded system to offer advanced services, which combined with the IoT to developing a smart city.

It is challenging to do a complete bibliometric review due to the lack of consensus in the literature in what are smart cities and the diversity of denominations that are used as synonymous. It is not easy to identify clear patterns in the data or generalize findings from studies showing specific country contexts. We have attempted to make more sophisticated use of the bibliometric methodology and quantitative content analysis (from text mining) and in this way a more comprehensive evaluation of the literature.

This inquiry is motivated by two research questions: (1) Which recent contributions have been driving the research agenda for smart cities and the Internet of Things. (2) Which emerging topics in the literature are likely to set the stage for future work?

This paper is structured as follows: In the next section, a conceptual review of smart cities and the Internet of Things. In section 3, the method and data are described; there is an explanation of the search terms adopted for retrieving the data and tools used for analyzing it. Section 4 provides the results of the analyses. Finally, section 5 presents the outcomes of the present paper concluding viable avenues for further research and other promising approaches to inform the inquiry concerning smart cities and a discussion on the limitations of the study.

THEORETICAL BACKGROUND

Internet of things (IoT)

The networking of people, things, and data is known as the Internet of Things (IoT) and brings about an increase in people's well-being through home automation systems, intelligent parking, among others (BATALLA, MASTORAKIS, MAVROMOUSTAKIS et al., 2017). For De Matos, Amaral and Hessel (2017) the basic idea of IoT is the generalized presence around people, and a variety of things or objects such as RFID tags, sensors and so on that connect to achieve common goals. The term "Internet of Things" came from the founders of the MIT Auto-ID Center, with mention of Kevin Ashton in 1999 and David L. Brock in 2001 (ASHTON, 2009; BROCK, 2001). The term "Auto-ID" refers to the identification technologies used to automate, reduce errors and increase efficiency in industries; they include bar codes, smart cards, sensors, voice recognition and biometrics (SANTUCCI, 2010). According to Santucci (2010), it was only in 2005 that the concept of the Internet of Things gained prominence when the International Telecommunication Union (ITU) published the first report

on the subject. Then, adopting a comprehensive and holistic approach, suggesting that the Internet of Things will connect the objects in a sensorial and intelligent way, combining for the identification of the items: sensors, wireless networks, and nanotechnology. For Sundmaeker, Guillemin, Friess et al. (2010), this is only the beginning; the author predicts between 50 and 100 billion devices connected by 2020.

The Internet of Things in recent years has been generating new challenges for the area of Information Technology and communication. Where the connection of the physical and virtual worlds causes the characteristics of the data sources to undergo constant changes activating new forms of communication between people and things, and between things. Therefore IoT promises to create a world where all the objects around us are connected to the Internet and communicate with the least human intervention (DE MATOS, AMARAL and HESSEL, 2017). For the success of these implementations, IoT relies on the practical solution to some technical challenges including improved sensor capabilities, sensor miniaturization, Big Data handling, and efficient remote data management as well the implementation of open and secure processes for the various IoT scenarios (BATALLA, MASTORAKIS, MAVROMOUSTAKIS et al., 2017). According to Vashi, Ram, Modi et al. (2017) the proliferation of communication devices with activation, access to new sources of information and the evolution of the mobile system, favors new revolutionary applications that contribute to the evolution of IoT. According to the author, the use of a scalable cloud-based framework allows the flexibility needed to meet the diverse needs of different sectors. Allowing networks, computing, storage and visualization to separate, thus enabling independent growth in all sectors, but complementing each other in a shared environment (VASHI, RAM, MODI et al., 2017).

Vashi, Ram, Modi et al. (2017) state that there is a radical Internet revolution going on, not only is a network that interacts with the connected objects extracting information from the environment sensory and interacts with the physical medium but also checks patterns in the network to provide information, new applications, and communication. All of this is driven by wireless technology such as Bluetooth, radio frequency identification (RFID), Wi-Fi and telephone data services all embedded with sensor devices and triggers. With the advances and convergence of microelectromechanical (MEMS), wireless and digital electronics technology, new miniature wireless has emerged with the ability to detect, compute and communicate over short distances. These devices form a wireless sensor network (WSN) with a full application in environmental monitoring, infrastructure monitoring, traffic monitoring, and retail (VASHI, RAM, MODI et al., 2017).

Vashi, Ram, Modi et al. (2017) presents a classification of three components necessary for the Internet of Things: a) Hardware, composed of sensors and triggers grouped with communication; b) Middleware, multi-device interface software, on-demand storage, and development tools for data analysis and c) Display interface for new visualization and interpretation tools that can be widely accessed on different platforms and can be designed for different applications (VASHI, RAM, MODI et al., 2017). Kim (2016), considers three essential factors for the diffusion of IoT, humans, factories, and cities. For the author, the factories are considered more critical, due to the rapid innovation that has been occurring in the production and recommends that in the initial phase of IoT economic agents focus on the hardware sector and later on the software sector, as services based on Big Data (KIM, 2016).

IoT Technology elements

IoT has been gaining momentum quickly by manufacturers and more recently by service companies. The reason for adopting this technology lies in the technological, social and competitive pressures that drive companies to innovate and transform (KIM, 2016). Moreover, as technology advances, communication and processing capacity for increasing interconnectivity becomes more accessible (SUNDMAEKER, GUILLEMIN, FRIESS et al., 2010). Although each author has a peculiarity regarding the most critical factors in the IoT, both agree that the connectivity and data, big data, are essential for the development of new applications (BATALLA, MASTORAKIS, MAVROMOUSTAKIS et al., 2017; KIM, 2016; VASHI, RAM, MODI et al., 2017). In this context, three technologies are advancing rapidly, radio frequency identification (RFID), wireless sensor networks (WSN) and big data and business analytics.

1) Radio frequency identification (RFID), uses radio waves to capture data, allows automatic identification (KIM, 2016).

2) Wireless sensor networks (WSN), have attracted attention to research in different disciplines due to the increasing availability of microprocessors with wireless communication (LANGMANN, NIEDERMEIER, DE MEER et al., 2013). WSN, consisting of devices equipped with autonomous sensors, to monitor physical or environmental conditions, together with RFID systems can track the status of such things like location, temperature, and movements (KIM,

2016). In recent years, sensor technology in networks has advanced enabling new applications mainly with IoT. Its use appears in the security and protection fields as well as the IoT devices being deployed to build the so-called "Smart Cities" (LANGMANN, NIEDERMEIER, DE MEER et al., 2013).

3) Big data and business analytics, IoT, with its embedded sensors capture large amounts of data and transmit it to business intelligence and analytics tools. This data is used to solve business problems and provide value-added services to customers (KIM, 2016). This significant amount of data requires computational intelligence of software techniques for data analysis to maintain, retrieve, store and send information. Thus, the big data contains extensive information generated by IoT technology (DEY, HASSANIEN, BHATT et al., 2018). The big data analysis is the current topic of research, however, for the handling of structured and unstructured data requires tools and techniques of highly specialized knowledge to use them and to understand their concepts (FOWDUR, BEEHARRY, HURBUNGS et al., 2018).

Smart cities

Studies on the phenomenon of smart cities are relatively recent, emerged from the beginning of the years 1990 (HAJDUK, 2016), gaining strength after the survey of Bastelaer "the case: the digital city of Amsterdam", (VAN BASTELAER and LOBET-MARIS, 1998). From then on, a series of successive advances in the subject were emerging. For Cocchia (2014), technological situations such as the emergence of the Internet, global environmental policy situations, investments and strategies in digital cities and research on these themes were the causes for the increase in the articles published on Smart / Digital City after 2009 (COCCHIA, 2014).

The concept of Smart City has several definitions: city of knowledge, sustainable city, and digital city. Until the 90s, the term "digital cities" was the most widely used term, today the most used is "smart cities" Digital was understood as the access to computers and the implantation of the Internet in the urban space (QI and SHAOFU, 2001). Intelligent refers to context-sensitive computer processes, dealing with a large data volume (Big Data), cloud networks and independent communication between various objects (Internet of Things - IoT) (SU, LI and FU, 2011). Intelligent here is synonymous with a city in which everything is environmentally sensitive that produces, consumes and distributes plenty of information in real time (DAMERI, 2013).

Many elements and dimensions that characterize an intelligent city have emerged from the analysis of existing literature (ALBINO, BERARDI and DANGELICO, 2015). Descriptions of smart cities include better quality for people and communities, as well as information and communication technology. The context of a smart city is related to a defined geographical area where citizens benefit regarding the well-being of high technologies, logistics, energy production among other factors enabling the inclusion and participation of citizens in environmental quality (DAMERI, 2013). For Cocchia (2014), the diffusion of Smart Cities is mostly driven by technological progress, and this phenomenon is spreading rapidly, and the result has been a new and innovative idea about the city and urban life: more beautiful, more inclusive, greener and cleaner. Smart City is now seen as a vital strategy to improve the quality of life for billions of people living in cities around the world (COCCHIA, 2014). In the new digital economy, the perception of smart cities is increasing, provided by the integration of urban infrastructures with information and communication technologies, allowing public and private organizations to develop new product designs or services that are more customer focused (LI, NUCCIARELLI, RODEN et al., 2016).

Although the discussion on "smart cities" has gained momentum in recent years, its definition is not yet fully consolidated, and this is why strategic planning in this field is not yet widely explored (ANGELIDOU, 2014, 2015). For Angelidou (2014), strategic planning for smart cities is still a somewhat abstract idea because the subject is still not widely explored and conflicting interests by stakeholders, local governments, research institutions, and technology providers. Also, there is a tendency to believe that technological innovation has automatically transformed a city into an 'intelligent city.' Komninos (2011), argues that the smart solutions adopted by cities have had limited impacts on cities' competitiveness, employment, and sustainability. For the author, smart cities are not yet ready for the challenges of cities. Solutions occur due to the advancement of technology rather than the demand and needs generated. There is also the fact that cities do not implement solutions efficiently, the fact remains that a deeper understanding of what makes a town be classified as an 'intelligent city.'

For Angelidou (2014), the smart cities theme is still being explored. It is shaped by its local characteristics, priorities, needs, and available technology in addition to being influenced by global market forces. In the literature review, there is no single strategy for the conception of smart cities, and there are several ways that lead to different decisions leading to different results (ANGELIDOU, 2014). Many researchers support the integrated view of an intelligent city, arguing that no single system operates in isolation: transportation, energy, education, healthcare, buildings, infrastructure, food, water, and public safety (DIRKS and KEELING, 2009). For Kanter; Litow (2009), this concept must be diffused in every subsystem of an intelligent city to be seen as an organic whole. Several other authors share the idea of smart cities; however, the concept of the smart city is far from being limited to the application of technologies to cities. Due to the use of the term "smart cities" is proliferating without agreed definitions, this creates confusion among urban policymakers (ALBINO, BERARDI and DANGELICO, 2015).

For Albino, Berardi and Dangelico (2015), cities must find ways to manage new challenges, such as some cities that seek solutions that have positive long-term effects on the economy. Today, to create more innovative and efficient smart cities, they emphasize the use of Information and Communication Technologies (ICTs), but neglect to highlight the need for integration among diverse actors that support smart cities (KOMNINOS, 2011). In this sense, Komninos (2011), states that research should focus more on integration architectures between the digital and physical aspects of cities. Because the need for solutions that link the physical space and the digital elements of cities is much more significant than the demand for standalone applications and digital solutions and therefore, according to the author, creating integrated solutions is the key to higher spatial intelligence in smart cities. Although the number of smart cities detailed surveys has increased in the past two decades, there is no systematic framework for analyzing and cataloging operations models for smart cities. There is a need for more in-depth analysis as well as more detail to help the implementation of smart city initiatives (KOMNINOS, 2011).

Research into the spatial and economic structure of cities increasingly new development factors which include, among other things, the technology, which is extremely important in urban development, giving new possibilities, and also allowing savings in time and energy. Contemporary city is not only a physical structure but also a vast a network of modern technologies aiming to optimize consumption of the city's resources and processes to prevent adverse effects resulting from the of its functioning. In recent years, there have been ideas aimed at saving resources, spatial planning, and network to avoid the increase in costs resulting from the enlargement of the cities. An increasingly high-tech city is as smart cities, which are committed to saving money all kinds of resources, including financial, time or energy. The smart city concept is one of the most important and highly developed towards improving the quality of life of the inhabitant's competitiveness of cities. This Idea is the intelligent management of the typical urban space by city authorities, citizens and representatives of the new technologies industry. Smart cities are cities, which, using information and communication technologies, are more intelligent and efficient use of resources, and as a result of saving costs and energy, the conditions for delivering services and the quality of life residents.

IoT Applications in Smart Cities

IoT systems will become a vital tool for communicating between companies and their customers and significantly improve the functioning of urban agglomerations. The importance of this context raises the fact that an increasing proportion of the population goes through urbanization and until the year 2045 almost 70% of humanity will live in cities, so the number of people engaged with this technology is enormous.

The Internet of Things (IoT) is a new paradigm that combines aspects of computing technologies, wireless sensor networks, Internet communication protocols, sensing technologies, communication and devices with embedded technologies. Smart cities advance to an integrated and intelligent environment, where IoT is used to interconnect, interact, control, and provide insights into the various fragmented systems within cities. A large number of interconnected devices, as well as a significant amount of data generated by them, provide unprecedented opportunities to address urban challenges. These technologies are merged with urban systems to form an environment where the real and digital worlds meet and are continually in a synergetic interaction.

Several industries and Academia efforts have been placed on IoT technologies applied to smart cities. Internet of Things (IoT) applications in smart cities and smart communities, involving real-time data streams and have grown continuously. These

include vehicle traffic detection, parking occupancy and bookings, security and surveillance, air quality monitoring, and even intelligent garbage cans. These applications promise to improve the lives of citizens such as health, safety and convenience (KRISHNAMACHARI, POWER, KIM et al., 2018; RASSIA; PARDALOS, 2017).

However, the first generation of IoT deployments for smart cities has several challenges that represent a barrier to adopting more. Vendors were developing proprietary solutions vertically integrated and competed for IoT. The adoption by the city is inhibited because cities come to understand that products from different suppliers do not work with each other. This lack of interoperability limits the possibility of connecting different data streams or developing fundamentally new applications to achieve higher value over time (KRISHNAMACHARI, POWER, KIM et al., 2018). However, the technologies are close to being standardized, and industry actors are already active in the production of devices that leverage these technologies to enable applications of interest to smart cities. These facilitating technologies, also, reached a level of maturity that allows the practical realization of IoT solutions and services, from field trials that will help clarify the uncertainty that still prevents a massive adoption of the IoT paradigm (AVIJIT and CHINNAIYAN, 2018; ZANELLA, BUI, CASTELLANI et al., 2014).

The success of these initiatives implies the contribution of all parts of the city. Policy, stakeholders, the company, the community, and the citizen should work together more transparently. On the other hand, many Smart City initiatives are being used intensively (CHOURABI, NAM, WALKER et al., 2012). Thus, academic and professional researchers still have to do a great job on technical and technological challenges. Several fields of ICT such as IoT, artificial intelligence (AI), Big data analysis, nano-technology are involved in creating scenarios for more Smart City (ARROUB, ZAHI, SABIR et al., 2016).

METHOD

Based on the bibliometric principle that knowledge of the disciplines is concentrated in only a small proportion of critical academic journals, we retrieved citation data from the web of science was used to conduct the searches and retrieve publication data. All available citation index databases were used in the search. These citation indexes also contain a record of the references cited by the authors of the covered publications. This allows the use of cited reference searches and various citation analyzes. Searching all of the citation index databases was done to get a sense of all scientific disciplines and areas contributing to the smart cities and the Internet of things research.

Method of text mining, additionally know as text analytics is the way toward understanding data from an arrangement of documents. In this research was utilized a bag of words procedure and the primary record was the author's keywords and designed to discover valuable knowledge from content. We provide a pre-processing step with a preliminary statistics study of web of science outputs (e.g.: the frequency of each word, correlation among words, association among words) them according to the results applied a set of techniques to reduce the problem of dimensionality (convert the text to lower case, remove numbers, punctuations, extra white spaces, English's stop words (dropping conventional terms), stemming (usually refers to a crude heuristic process that chops off the ends of words in the hope of achieving this goal correctly most of the time, and often includes the removal of derivational affixes, feature selection). The second step with dataset modeling (training dataset) and the transformation of outputs into a dataset (bag of words, n-grams). Finally, the construction of our text analysis model using, for dimension reduction, topic modeling, to have responses, unsupervised learning with k-means clustering (to minimize the average squared Euclidean distance of documents from their cluster centers where a cluster center is defined as the mean or centroid of the documents in a cluster). Additional techniques include social network analysis for text analytics (both deal in large quantities of data, much of it unstructured), clusterization, correlation, and so forth.

On Web of Science, using a search string to search by Topic includes in the results hits in the publication title, abstract, author, and keyword and so on. This resulted in 486 hits from Clarivate Analytics' web of science (Web of Science Core Collection; Topic: ("smart cit*" AND "internet of thing*") where the asterisk represents any group of characters, including no characters, only Articles; the whole period, without exception. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI. Book chapters, editorial materials, book reviews, proceedings were removed. Filters were applied being eliminated articles in biotechnology, microbiology, chemistry, optics, oceanography, and veterinary. We searched all issues in smart cities and IoT from 2011 to 2018. Data for 2018 are incomplete but were analyzed in this study. Restrictions were applied

to the subject area. All searches were performed on October 31st, 2018. The registers are describing the whole corpus of publications mentioning the Topic.

Once the 486 relevant articles from 1404 hits were identified the authors independently read them and assessed and coded their content about the following categories: Authors and institutions, citations, journals, keywords, country, and language. Further analysis has been conducted through the R software (ex. NLP, FactoMinerR, tm, SnowballC, wordcloud packages) that scrutinizes a text by counting the frequency of the most mentioned words as 'keywords.'

DATA ANALYSIS

Primary information about data: articles (486), sources (194), author's keywords (1561), average citations per article (9.586), due to the brief period of research of the theme, authors (1626), author appearances (1968), authors of single-authored articles (39), authors of multi-authored articles (1587), articles per author (0.299), authors per article (3.35), co-authors per articles (4.05) and collaboration index (3.57).

The most productive author is Munoz with eight papers, followed by Barnaghi, Sanchez, Skarmeta and Sotres with six papers each, and followed by Ahmad, Chang, Curry, Gutierrez, Kantarci and Moessner with five publications each.

Top 15 manuscripts per citation are Zanella, Bui, Castellani et al. (2014), Botta, Donato, Persico et al. (2016), Jin, Gubbi, Marusic et al. (2014), Perera, Zaslavsky, Christen et al. (2014), Sanchez, Muñoz, Galache et al. (2014), Vlacheas, Giaffreda, Stavroulaki et al. (2013), Bellavista, Cardone, Corradi et al. (2013), Gravina, Alinia, Ghasemzadeh et al. (2017), Sun, Yan and Zhang (2016), Raza, Kulkarni and Sooriyabandara (2017), Khorov, Lyakhov, Krotov et al. (2015), Rathore, Ahmad, Paul et al. (2016), Hashema, Chang, Anuar et al. (2016), Perera, Liu and Jayawardena (2015) and Mohanty, Choppali and Kougianos (2016).

Zanella, Bui, Castellani et al. (2014) provides a comprehensive survey of the enabling technologies, protocols, and architecture for an urban IoT and discuss the technical solutions and best practice guidelines adopted in Padova, Italy. The Botta, Donato, Persico et al. (2016) highlight the integration of cloud computing and IoT and develop a common middleware for future-oriented smart-city services. Jin, Gubbi, Marusic et al. (2014) present a framework for the realization of smart cities through the IoT who encompasses the complete urban information system, from the conscious level and networking support structure through to data management and Cloud-based integration of respective systems and services and forms a transformational part of the existing cyber-physical system. Perera, Zaslavsky, Christen et al. (2014) investigate the concept of sensing as a service model in technological, economic and social perspectives and identify the significant open challenges and issues. Sanchez, Muñoz, Galache et al. (2014) describe the deployment and experimentation architecture of the Internet of Things experimentation facility being deployed at Santander city (SmartSantander project). Vlacheas, Giaffreda, Stavroulaki et al. (2013) identify the main issues that may prevent IoT from playing this crucial role, such as the heterogeneity among connected objects and the unpredictable nature of associated services.

Regarding the language, English is visibly the dominant language of all the publications with 481 of 486 in English, according to web of science, only two in Portuguese language journal (Rizzon, Bertelli, Matte et al., 2017) but "Smart City: A Concept under Construction" published in English, and Santiago and Payao (2018) published in Portuguese. One Spanish journal with Stone, Knapper, Evans et al. (2017) but published in English "Urban eyes: Platform for City Information Management," one French journal (LEMOS, 2016) but published in English "Performative sensitivities", and, finally, in Polish, Rot (2018). Many authors from countries like Spain (LANZA, SÁNCHEZ, GUTIÉRREZ et al., 2016; TOLOSANA-CALASANZ, 2016), Italy (CHATZIGIANNAKIS, VITALETTI and PYRGELIS, 2016; BARCELO, CORREA, LLORCA et al., 2016) and Portugal (ABREU, VELASQUEZ, CURADO et al., 2017) publish their papers in English. Considering China, Li, Cao e Yao (2015) and Peng, Fang, Ranaei et al. (2017) also produced in English. A more detailed analysis shows, therefore, all the production in the English language.

China, Spain, and the USA are the dominant Countries (most productive) with 56, 52, and 50 articles respectively. In the sequence, we have the following countries: Italy (41), India (33), United Kingdom (31), Korea (20), Australia with 16 articles, Saudi Arabia (14), Canada (13), Pakistan (10), Greece, Japan, and Malaysia with nine articles each, and finally, France with eight articles.

About relation to total citation per country we have (total citations; average article citation): Italy (1412; 34.439), Australia (530; 33.125), China (469; 8.375), Spain (412; 7.923), USA (249; 8.032), United Kingdom (249; 8.032), Korea (218; 10.900), Greece (157; 17.444), Malaysia (93; 10.333), Russia (81; 40.500), and Germany (71; 11.833).

Publications can list multiple countries. What we should highlight the role of European Countries as Italy, Spain, United Kingdom, Greece, and Germany adding the role of the Asian Countries as China, Korea, and Malaysia. Italy is the leader with more total citations (ZANELLA, BUI, CASTELLANI et al., 2014; BOTTA, DONATO, PERSICO et al., 2016). There is significant dispersion in average article citations for the top nine Countries (from 5.980 to 40.500).

As we can see in Figure 1, they are the collaboration between countries. We can highlight the European hub with Italy, Spain, Germany, Greece, and the United Kingdom. It is otherwise, USA, India, Korea, Pakistan, and Australia in another cluster. China is a new hub research. We can highlight that all significant research producing countries in the area have international partnerships.

Figure 1
Country Collaboration
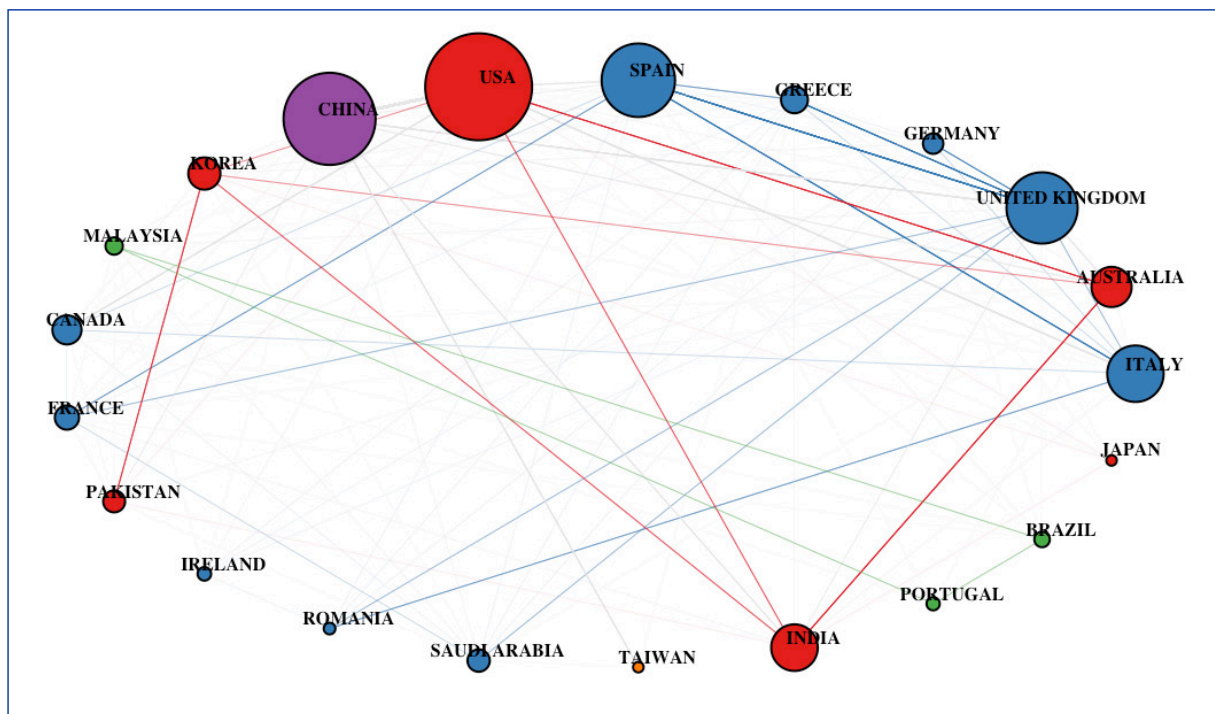
Source: Elaborated by the authors.

Institutions (Universities)

The Universities producing the publications (Web of Science) are very dispersed, with a concentration in European and Asian Universities (Box 1). From the University of Surrey: Pozza, Nati, Georgoulas et al. (2015) and Kolozali, Puschmann, Bermudez-Edo et al. (2016). From the University of Murcia: Sanchez, Lopez, Skarmeta et al. (2013); Jara, Fernandez, Lopez et al. (2014) and Garcia-Carrillo and Marin-Lopez (2016). From University of Cantabria: Sanchez, González-Contreras, Agudo et al. (2017); Perez-Gonzalez and Daiz-Daiz (2015); Diaz-Diaz and Perez-Gonzalez (2017) and Lanza, Sánchez, Gutiérrez et al. (2016).

Box 1

Publications / universities

Universidade	País	Artigos
University of Surrey	United Kingdom	12
University of Bologna	Italy	10
King Saud University	Saudi Arabia	9
Universidad de Cantábria	Spain	9
Comsats Institute of Information Technology CIIT	Pakistan	7
Dalian University of Technology	China	7
University of Murcia	Spain	7
Chinese Academy of Sciences	China	6
Kyungpook National University	South Korea	6
University of Granada	Spain	6

Source: Clarivate Analytics' Web of Science (2018).

Conferences and Journals

The most productive journals or conferences (Box 2) in research on smart cities and IoT by numbers of articles published are as follow:

Box 2

Productive journals and conferences

Source	Articles
IEEE ACCESS	45
FUTURE GENERATION COMPUTER SYSTEMS-THE INTERNATIONAL JOURNAL OF ESCIENCE	38
IEEE INTERNET OF THINGS JOURNAL	38
SUSTAINABLE CITIES AND SOCIETY	11
IEEE COMMUNICATIONS MAGAZINE	10
INTERNATIONAL JOURNAL OF ADVANCED COMPUTER SCIENCE AND APPLICATIONS	9
SUSTAINABILITY	9
IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS	8
INTERNATIONAL JOURNAL OF DISTRIBUTED SENSOR NETWORKS	8

Source: Clarivate Analytics' Web of Science (2018).

The leading journal of research on smart cities and the Internet of things, namely IEEE Access with 45 papers, Future Generation Computer Systems: The International Journal of eScience with 44 papers, IEEE Internet of Things Journal with 38 papers, Sustainable Cities and Society with 11 papers. IEEE Communications Magazine with ten papers. Another important journal is IEEE Sensors Journal. It is a refereed journal published by IEEE. Sensors publish articles focuses on the numerous sensor technologies spanned by the IEEE, and on emerging sensor technologies.

The fact that deserves to be highlighted it is due to being a recent research area. We must highlight that importance of the conferences (annals). Many of these conferences publish annals in book format; thereby making more widely disseminated the subject of research. Important to highlight the importance of scientific events in the development of the research area where we have, for example, IEEE 27th International Conference on Advanced Information Networking and Applications Workshops (WAINA), IEEE International Conference on Future IoT Technologies (Future IoT), and International Conference on Intelligent Networking and Collaborative Systems (INCoS).

Keywords and word associations

A word cloud (Figure 2) is another kind of visual example of the spirit of Zipf's Law (BURKETTE, 2015). The word frequencies in many languages follow Zapf's law in that the most frequent word occurs twice as often as the second most frequent, and three times as often as the third, and so on. The word cloud was tested for Zipf's Law with a regression equation 5.043–0.742x. The Heaps' law describing the sublinear growth of vocabulary size with the length of a document, and the topicality of document collections, which encode correlations within and across documents absent in random null models (0.654 + 0.788x). Its relative frequency determines the size of each word in the cloud in the selected text. The more frequently a word is found, the more significant it looms in the cloud. Figure 2 shows the word cloud for smart cities and the Internet of things research field. We tried a search with a representative keyword for the period (2011-2018). The frequencies of the words are represented between parentheses for each keyword. The most frequent words are the Internet (290), things (260), smart (257), city (196), IoT (130), data (126), network (83); computing (82), sensor (59), Big (56), and Cloud (51). To improve granularity for key-words with tokenization (N-gram): Internet of Things (191); Smart City (105); Smart Cities (87); Internet of Things (IoT) (61); IoT (46); Big Data (45); Cloud Computing (35); Security (21); Smart (21), and Fog Computing (19), wireless sensor networks (12), Edge computing (11), Energy (11), Privacy (11). For web of science's keywords-Plus we have: Internet (117); Things (99); Networks (48); Smart Cities (37); Challenges (35), Wireless Sensor Networks (35); Management (32); Cloud (30); IoT (29); Systems (29); and Big Data with 19 each.

**Figure 2**

Word cloud limited to 200 of 951 keywords
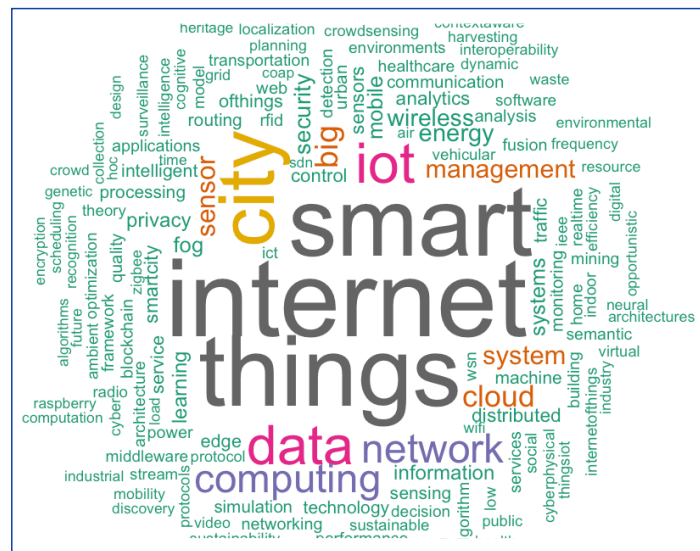
Source: Elaborated by the authors.
NOTE: Tested Zipf`s law (regression 5.043 -0.742X).

We found the association term, to fetch the words related to the keywords, in the term-document matrix. (Setting the Pearson' correlation coefficient limit to 0.2): 1) for "IoT": privacy challenges (.34); dataset (.25); intrusion prevention (0.25); IoT security (.25); security internet of military (.25); security predictive (.25); self healing (.25); transition (.22); collaborative (.22), and vulnerabilities (.22). 2) for "computing": fog (.64); edge (.57); computing dew (.36); multicloud (.27). 3) for "sensor": wireless (.61); networks(.41); gian (.37); parameters (.37); things wireless (.24). 4) for "big": data (.64); digital forensic (.26); forensic (.26); readiness (0.26); reduction (.26); system forensics (.26); analytics (.24). 5) for "cloud": software as (.38); based (.30); fog (.28); pervasive (.26); community (.26); systems middleware (.25); crowd control (.25); robotics (.25); task (.25); edge (0.24); physical (.20); off loading (.20).

For a special analysis of term "things": internet (.74); smart (.23); representational (0.21); REST (Representational State Transfer) sensors (.21); state (.21); and transfer (.21).

Figure 3

**Hierarchical clustering of key-words**
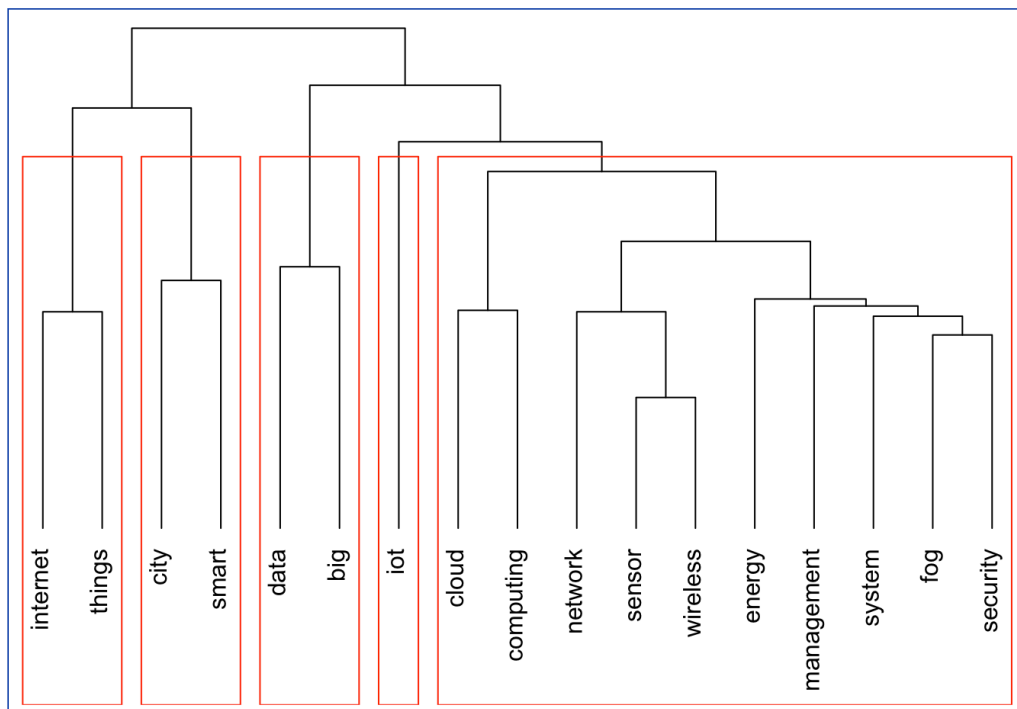
Source: Elaborated by the authors.

For the hierarchical clustering, we need to be removed the sparse terms. We set the sparsity at 0.95 so that terms with at least that sparse percentage will be removed. Then compute the distance matrix and plot the dendrogram. By cutting the dendrogram into five clusters (Figure 3). Observe that "smart" and "city" are both in their clusters. Another cluster with "internet" and "things," and the third cluster with "big" and "data." We have many terms for cluster 5, That makes sense because the terms constitute the smart cities and IoT arena describing "recent" information about the theme, as IoT; cloud computing; wireless sensor networks; energy management; security and fog computing. A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. Energy management is used as a solution to reduce the demand and conserve energy during the peak period and improve energy efficiency and quality of life and protect the environment. A more significant challenge and a vital issue is IoT security for the secure development and operation of scalable IoT applications and, finally integration of cloud computing and the Internet of things for smart cities.

As the research of Wiratunga, Lothian, Chajraborti et al. (2005), we generate all possible pair-wise keyword co-occurrences (Figure 4) converting only those that pass a significance test into a social network analysis and their clusters. The second and a more complex cluster with the Internet of Things, Big Data, Cloud, architecture, management, security systems, and wireless sensor networks. The first with a focus on the protocols and scheme as MQTT (Message Queue Telemetry Transport) and CoAP (Constrained Application Protocol).

Figure 4

keyword co-occurrences
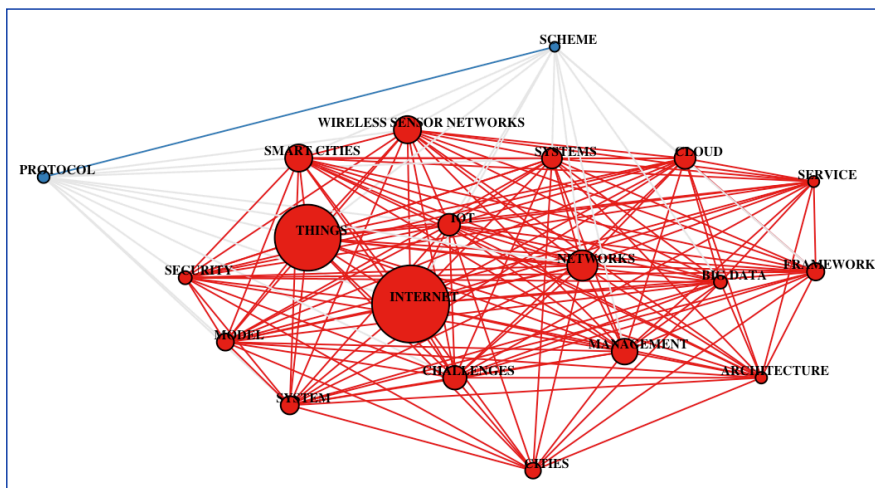
Source: Elaborated by the authors.

A co-word method (Chen, Chen, Wu et al., 2016) based on keywords from smart cities and IoT is proposed to map the research trends. Firstly, the keywords of smart cities and the Internet of Things are used to describe the research topic statistically. Then, co-word analysis (Figure 5), including cluster analysis is adopted to study the relationship of each research topic. The results show that the focus of researchers consisting of two segments described a follow: 1) energy efficient; ad hoc networks; protocol; wireless sensor networks, routing protocol; secure; mesh networks. 2) Healthcare; privacy; security; big data; sensor; perspective; technologies; mobility; performance; algorithm; demand; models; sensor network; architecture; privacy among others.

Figure 5

Co-word analysis: Conceptual Structure Map of the Field
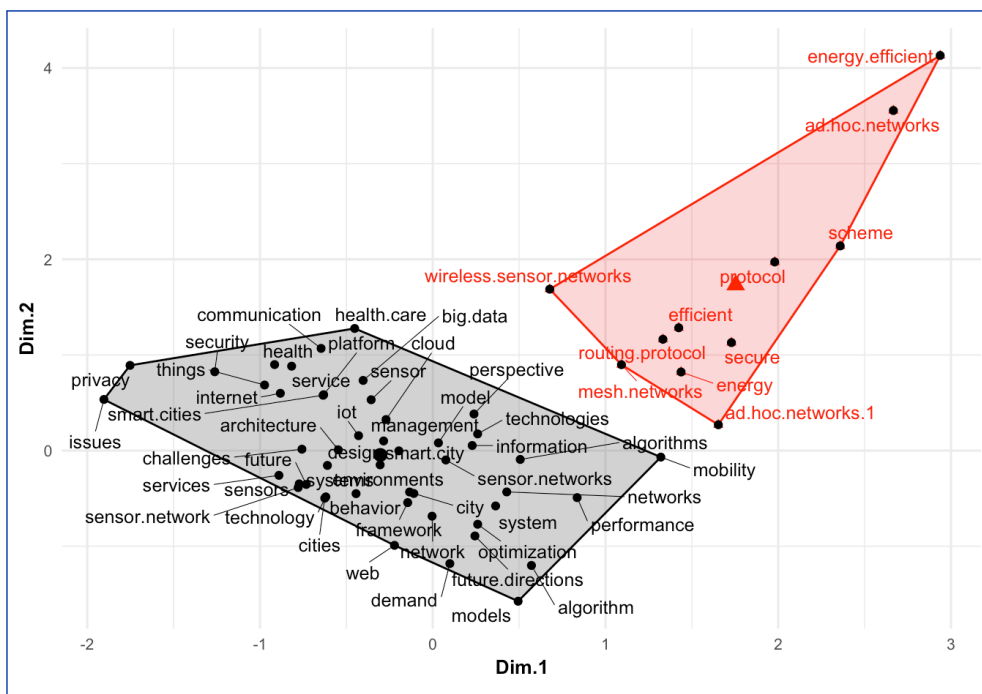
Source: Elaborated by the authors.

DISCUSSION AND CONCLUSIONS

The future of smart cities and the Internet of Things: research agenda

In the above analysis, we critically evaluate smart cities and IoT research and develop a research agenda that provides a foundation for stimulating new directions of research. The research agenda we are suggesting in this paper comes directly from gaps we identified in our review.

Smart cities and IoT are a "booming" phenomenon has been reported, mainly using samples from the context of developed countries (Figure 1) as Spain, China, USA, Italy, United Kingdom, Australia, Korea. However, early studies indicate that these regions are appearing in countries with innovation and reality very different from developed economies (e.g., Saudi Arabia, Pakistan, Romania, Malaysia, Brazil, Portugal in this research). The understanding of smart cities and IoT in developing economies is quite limited. Consequently, a more systematic research approach is needed to improve our understanding of smart cities and IoT phenomena on a broader range of cultural and institutional contexts. Is the institutional context the smart cities and IoT comes from makes a difference in the country's behavior?

Our review exposes that the relationship between smart cities, IoT, and innovation is under-investigated in the context of developed countries, and is even less in comparison to developing countries. There are a few recent studies on smart cities and IoT addressing the Moreover, some of the studies we reviewed, in particular, the qualitative works, focus on global success stories exclusively (Singapore, Seoul, San Francisco, Barcelona) (MAHIZHNAN, 1999; MARINE-ROIG and CLAVÉ, 2015a, 2015b), or typical examples of smart cities as: smart parking; car sharing services; traffic; public transport (mobility); clean energy; smart building; waste disposal; environment protection; citizen participation; digitalization of government; urban planning; education; business ecosystem; 5G LTE; internet speed; Wifi Hotspots; smartphone penetration; living standard. How the city is becoming smarter, thus, future research might ask questions such as:

- What makes a city, or region, becomes a smart city?

The quantitative content analysis is in its infancy. Several outputs have not been used in this article, such as Multiple Discriminant Analysis (MDA), Correspondence analysis, multidimensional scaling (an unsupervised learning technique), Self-Organizing Map, sentiment analysis, machine learning algorithm as LDA among others.

The computing cloud-based IoT and millions of devices or sensors connected with their applications do not create a homogeneous environment, and it is exposed to numerous threats. This issue results in a critical research question related to the management, not only of the infrastructure of an intelligent city but the security of its system and citizens.

Applications of the concept of the IoT in Smart Cities improve a significant challenge for architects of security systems and can open the door for security threats, ranging from vulnerabilities in the Distributed Denial of Service (DDoS) attacks to cross-site scripting (XSS) attacks. Hackers can quickly get a password to access them with administrator privileges, and then modify their system software to adapt them to criminal goals, for example, collecting personal data about citizens using public services, urban transport networks, with weak points in the authorization or authentication system. Intelligent meters as energy (smart grid), water (smart water grids), public health and safety, transportation). These are challenges both academics and mayors and their municipal administration.

A rising line of research is one that connects blockchain with smart cities and how blockchain can be a key enabler to solve many IoT security problems. Researches as Sun, Yan and Zhang (2016), Khan and Salah (2018), Banerjee, Lee and Choo (2018), Sharma and Park (2018), and finally Hammi, Hammi, Bellot et al. (2018) have addressed this issue in their recent research.

Some limitations of this study must be taken into account. The search results of this study mostly consisted of journal articles. Monographs, proceedings papers, dissertations, books or book chapters were not covered by the searches, although they also represent a part of the scientific discussion in smart cities. Older publications can logically have received more citations in total over the years than newer ones. No impact factors were used in analyzing the data of this study, except the most relevant papers as shown in the analysis. There are several other common criticisms of the Web of Science as the primary data source for bibliometric analysis and, consequently, for the text analysis, such as a bias towards publications from the English language, and the dependencies on journal impact factors. Papers published in other languages tend to have less impact on the research front (is the case of this research with 100% of articles in the English language). A large percentage of articles in English in the ISI Indexes thus reflect the international research front, where even researchers Asian, like Chinese or South Korean published in English.

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