ISSN: 1831-9424

European
Commission

JRC TECHNICAL REPORT

Bibliometric Analysis of Scientific Publications and Patents on Smart Cities

Puliga, G.
Bono, F.
Gutiérrez Tenreiro, E. G.
Strozzi, F.

Joint
Research
Centre

EUR 31389 EN

EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC129102

EUR 31389 EN

PDF ISBN 978-92-76-61752-5 ISSN: 1831-9424 doi:10.2760/074691 KJ-NA-31-389-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report: Puliga, G., Bono, F., Gutierrez Tenreiro, E. G. and Strozzi, F., Bibliometric Analysis of Scientific Publications and Patents on Smart Cities, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/074691, JRC129102.

Contents

Abstract

This work aims to figure out a landscape of the scientific and technological production of the Smart City concept. Smart Cities have attracted the attention of both academia and industry. However, the state of the art is still unclear and most of the focus has been on literature reviews without looking at technological aspects. To achieve this objective, a scientometric dynamic methodology has been applied to paper and patent data. This methodology combines traditional systematic reviews with the analysis of networks and keywords. These dynamic analyses allow depicting the evolution of Smart City, the research and technological directions, the critical areas, and the emerging topics and it reveals the position of the technological evolution concerning the scientific one. These techniques reveal that while research papers are concerned with social aspects, the technology is mainly focused on specific technical solutions without completely looking at the citizen role. Moreover, patents are not fully embodying sustainability concepts yet.

1. Introduction

A Smart City (SC) is an urban area in which, thanks to the use of digital technologies, it is possible to improve the infrastructures and services to citizens, making them more efficient. The definition of SC, therefore, starts from the digital transformation in public transport and mobility; public lighting; energy management and distribution; urban security; environmental management and monitoring; waste management; maintenance, and optimization of public buildings.; communication and information systems and other public utility services. However, technology is not enough for a City to be a Smart City. SC refers above all to a sustainable, efficient, and innovative city, able to guarantee a high quality of life to its citizens, and technology is only one of the instruments to reach this goal.

SCs have attracted attention over the last few years from both academia and industry, as suggested by the sharp increase of publications, patents, and the fast-growing attention on the topic (Ingwersen and Serrano-Lopez 2018; Mora et al., 2017; Mora et al., 2019). In Europe, the 'Join, Boost, Sustain' movement formalised a declaration[1] signed by 86 representatives of European public administrations at local, regional, national, and Union levels committing to develop and innovate cities and communities into smart and sustainable places ensuring open and interoperable digital platforms and solutions across the European Union. The advent and widespread adoption of technologies for SCs are essential to meet the goals set by such European Commission priority policies as the New Green Deal and the Europe Fit for the Digital Age. The EC works closely with smart cities and communities to improve citizen quality of life and achieve the goals of the European Green Deal by encouraging and supporting the development of smart city technology across Europe.

The creation of Local interoperable data platforms, the establishment of Data Space for Smart Communities, and the creation of Local digital twins (virtual representations of the urban physical assets, processes and systems) are significant EC initiatives[2] that aim to bring together cities, businesses, SMEs, investors, researchers, and other key players in smart cities.

Finally, through the Horizon Europe research program and the DIGITAL initiative, the EC offers financial support for innovation and digital transformation in cities.

The Joint Research Centre is also contributing to the advent of Smart Cities, with several research and technical activities, addressing the various aspects of relevant technological innovation. The JRC E.4 Unit addresses the challenges of digital transformation (Baldini et al., 2019) of the urban environment and the AECO sector (Architecture, Engineering, Construction, Operation), through the development of Smart Buildings and Smart Infrastructures within the CITYSCASPES projects portfolio. A Smart City digital platform has been implemented at the JRC Ispra for the study of the standardisation and interoperability challenges related to the recent technologies (including wireless sensor networks and IoT devices). A JRC Living Labs initiative[3] is on-going to enable innovation, co-creation and start-up development in the fields of mobility and energy and studies, along with JRC studies and foresight analysis on Artificial Intelligence and twin Green and Digital transition (Muench S. et al., 2022) to support the policy development.

[1] https://www.living-in.eu/
[2] https://digital-strategy.ec.europa.eu/en/policies/smart-cities-and-communities
[3] https://joint-research-centre.ec.europa.eu/pilot-living-labs-jrc_en

Several definitions of SC exist. The most general one describes the SC as a system of systems that involves the combined links of people, institutions, technologies, organizations, environment, and infrastructures (Israelites et al., 2021), while Manfred et al. (2019) and Praharaj and Han (2019) recently define SC as a city where “investment in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance”.

It is difficult to gain a unique panorama of the heterogeneous and interdisciplinary features that continuously evolve in the SC wide-area (Camero and Alba 2019; Chauhan et al., 2016; Cocchia, 2014; Guo et al., 2019; Talari et al., 2017; Yigitcanlar et al., 2018a). A review of the state of the art would help to summarize what has happened in SC development. Until now, reviews only account for the analysis of scientific production with little consideration for technological development. Moreover, most of the literature shows a lack of systematic quantitative investigation and does not show a clear time evolution.

To fill this gap, the present paper will provide a systematic investigation of the journal publications (scientific knowledge) combined with a systematic review of the patenting activity (the technological evolution) (Caragliu and Del Bo, 2019). We developed an extended version of a well-known methodology called Systematic Literature Network Analysis (SLNA) (Strozzi et al., 2017) developed for scientific papers. SLNA consists of a methodology that uses a systematic procedure to extract the documents and use a network to represent and analyse the results. This allows us to have a quantitative tool to measure and analyse the bibliography (for this reason we can speak about bibliometric tools). Different from a descriptive review, a bibliometric review relies on objective measures and algorithms to identify emergent topics (Kim et al. 2016).

The new methodology (SLNA-P) analyses not only the scientific papers but also the technological production and then compares the findings.

Results show that most papers focus on several different areas, in particular, the recent trend on sustainability and mobility, while patents concern two aspects related to data: the Internet of Things (IoT) to collect data and 5G for telecommunication.

This article is structured as follows. In the second section, the state of the art is summarized. The third section presents the material and SLNA-P methodology. In the fourth and fifth sections, the analyses applied to papers and patents are presented. The sixth section discusses the research directions identified even considering the abrupt change in the way of life imposed by pandemic constraints and the last section suggests the final remarks.

2. State of the art

Over the years, several systematic literature reviews have been published on SC. Earliest literature reviews aimed at defining the SC concepts. The work of Cocchia (2014) firstly sought to find a unique understanding of the SC concept *per se*. At that time, already several definitions of SC existed, but no single one was universally acknowledged. Cocchia (2014) analysed the works on SC and *digital city* from 1993 to 2012 and pointed out commonalities and differences between the two concepts, but over time, the concept of SC swallowed that of *digital city*; however, some characteristics can be traced back from it to define an SC: the role of technology and innovation, the environmental requirements, and the economic and social aspects.

Six sub-areas holding distinct SC concepts have been identified (Winkowska et al., 2019): smart economy, smart people, smart living, smart environment, smart governance, and smart mobility. Large part of the works focuses on Environment (for example energy efficiency), Mobility applications (Intelligence Urban Transport systems) and more recently healthcare actions (Quijano-Sánchez et al., 2020), while Governance and Living are relegated to a secondary place and People and Economy are barely mentioned. Most of the attention has been drawn to enabling technologies, like the IoT and Big Data mainly in terms of predictive analytics, but probably soon cyber-physical systems and intelligent applications will be adopted (Camero et al., 2019; Gupta et al., 2019; Souza et al., 2019; Quijano-Sánchez et al., 2020). In turn, themes such as smart people, smart governance, and smart economies, that characterize the social impact, governance and policy, performance indicators, standards, implementation barriers, benefits, and strategy of SCs have received moderate attention (Gupta et al., 2019; Souza et al., 2019).

The SC governance has highlighted a particular concern because of the need of involving a wide range of stakeholders and because of low citizens involvement (Guo et al., 2019; Marrone et al., 2018; Meijer et al., 2015; Pereira et al., 2018; Quijano-Sánchez et al., 2020; Ruhlandt, 2018; Winkowska et al., 2019).

Other publications focus on the implementations of the SC, some of which review the tools adopted in terms of Information and Communication Technologies (ICT) that should allow for reducing complexities and integrating stakeholders (Bokolo, 2020). Interests regard the key role of data mining, machine learning, and statistical methods with studies addressing their adoption in SC (Soomro et al., 2019; Chauhan et al., 2016; Moustaka et al., 2019; Ahmed et al., 2020; Brohi et al., 2018).

Another set of reviews focuses on the development of SC concepts and their links with the sustainability topic (Trindade, 2017; Toli, 2020; Zheng, 2019). Often ICT has taken a predominant role, without considering other essentials such as economic and social ones. The new direction is that people must be smart ("people-first smart") to achieve sustainable urban development; this may lead to issues concerning security and privacy. With this people-centric approach, governance is at the core of research agendas.

Another main area regards the evaluations of SC performance and the definition of Key Performance Indicators (KPI), which still has been barely addressed (Purnomo et al., 2016; Quijano-Sánchez et al, 2020). SCs are costly and long-term returns are unknown, they suffer the fact that the implementation is relatively new, and results cannot be fully measured yet (Lim et al., 2019).

Kunzmann (2020) speculated on some implications of the Covid-19 pandemic on SC development. He observed that it will be impossible to return to the former way of life. Covid-19 disruption will accelerate the trends that have been already observed in the early decades of the 21st century, concerning urban mobility, work conditions, and consumption of food, and entertainment.

3. Material and Methods

3.1. Methods: SLNA-P

The proposed methodology follows the steps mentioned by Colicchia and Strozzi (2012) by using different tools for bibliometric analyses. In Figure 1 SLNA-P is represented. It consists of the following steps

- Systematic Literature Review (SLR) for papers and patents

  The Systematic Literature Review proposed by Denyer and Tranfield (2009) use the CIMO-logic as a fitting methodology to frame the scope of the literature review. It consists in defining the Context (that refers to the systems/organizations/problems to be studied), the Intervention (that refers to the effect of the events/actions studied), the Mechanism (that refers to the process according to which an intervention leads to the specific outcome) and the Outcome (that refers to the results of an intervention brought by the use of a mechanism). In Table 1 the application of CIMO logic considered in SLNA-P is shown. Then selection criteria such as considering only English documents or a specific time window etc., are defined (Kembro et al., 2014).

- Basic and advanced Statistics for papers and patents

  Basic statistics allows having a general picture of the topic. The evolution of the number of works and the field over the years are some examples. Burst detection, a tool of advanced statistics, has been proved to be useful to detect the increase of interest in some topics. Burst detection algorithm provides (Kleinberg, 2003) a dynamic method to identify the emergence or growth of research topics according. Mainly It compares the frequency of the item with the mean frequencies of others and, fixing some parameters, it decides if it is a burst or not. In SLNA-P the burst detection algorithm is applied to the author's keywords of the papers and the technical concepts for the patents since they represent the content of the documents.

- Network Analysis for papers and patents

  The Network Analysis (NA) uses network representation of the documents to extract information. Given a set of papers/patents, it is possible to build different networks (e.g. citation networks where the nodes are the documents and the links the citations, or the author keywords networks where the nodes are the keywords and the links represent their co-occurrence in the papers).

  The citation network permits to map the flow of knowledge, where nodes are publications/patents and links are citations occurring between them. The links between the nodes represent the flow of knowledge from cited documents to citing ones. From the general network, the most important connected component must be identified. It allows distilling the connected components with many nodes and it provides a dynamic perspective of the research (Lucio-Arias and Leydesdorff 2008; De Nooy et al., 2011). From the citation network, it is possible to extract the Main Path that allows identifying the backbone of the research tradition (De Nooy et al., 2011; Lucio-Arias and Leydesdorff, 2008), recognizing documents that are hubs for later works (Strozzi et al., 2017).

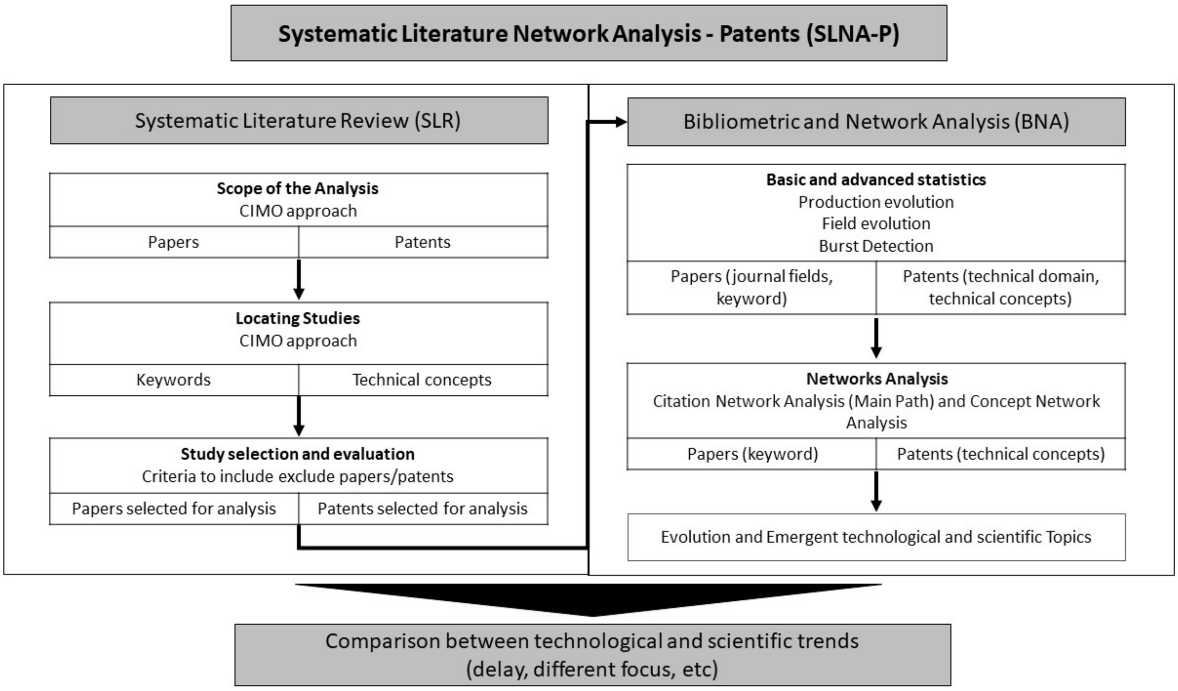
  The concept networks are other important networks that help to identify research areas. The nodes are the main concept of the documents and the links represent that two concepts have been used together in one or more documents. The analysis of the concept networks is based on clustering and mapping networks (Waltman et al., 2010).

The Visualisation of Similarities (VoS) mapping technique and clustering have been used. Each cluster of concepts shows a group of concepts that appear most often together, and it may represent a research area.

- Merging the results of papers and patents

  The results emerging from the previous steps of patents and publications are compared for finding technological and scientific trends and commonalities and differences existing between them.

Figure 1 SLNA-P Methodology Research Schema



3.2. Materials

To apply the SLNA-P, the data have been extracted from two sources: Scopus and Orbit Intelligence (https://www.questel.com/orbit-software-suite/orbit-intelligence). Scopus is the largest abstract and citation database of peer-reviewed documents. It provides a comprehensive overview of the world's scientific papers. Orbit Intelligence is a leading global intellectual property software dedicated to patents. The platform delivers access to the largest patent database.

To analyse paper and patent data, Pajek, SCI2, and VoS Viewer – free software - have been used. Pajek (**http://mrvar.fdv.uni-lj.si/pajek/**) is a program for the analysis and visualization of networks and graphs. It is continuously updated. Sci2 (**https://sci2.cns.iu.edu/user/index.php**) is a modular toolset designed for temporal, geospatial, topical, and network analysis, and visualizations of datasets. VOSviewer (**https://www.vosviewer.com/**) is a software tool for constructing and visualizing bibliometric networks, that may include journals, researchers, or individual patents or publications, and they can be constructed based on citation, bibliographic coupling, and co-citation.

4. Application of SLNA-P

3.3. Systematic Literature Review

3.3.1. Scope of the analysis for papers and patents

Table 1 CIMO logic application for papers and patents

Context	City
Intervention	Practices and tools for Smart City development
Mechanism	Implementation of digital and policies processes
Outcome	Increasing the Smartness of the city

3.3.2. Locating studies for papers and patents

Following the objective of this study, several search keywords have been proposed and tested. The search keywords were derived from a continuous engagement of a panel of experts from academia and industry and continuously refining the information extracted from a set of papers. This process ended up with the string of keywords for both patents and papers including the words "Smart City" and not the words Distributed Denial of Service (DDos), cyberattack, cyber-attack, Cryptography, Security of Data, Network Security. Topics specifically related to cybersecurity have been filtered out in the present analysis because the main aim of this work is to address the social and organisational aspects and impacts of SC implementations whereas the challenge of ensuring IT security is specific and cross-sectorial.

3.3.3. Study selection and evaluation

Inclusion criteria were defined to evaluate the relevance of the papers to be added as reported in Table 2.

Table 2 Papers inclusion criteria

Inclusion Criteria	**Rationale**
Articles published in peer-reviewed journals	Peer-reviewed journals are works of higher quality
Selection of papers without constraints on publication year	A large time window allows seeing the evolution of the topic
Search Field: Title	Research in the title permits to identify the article strongly focusing on Smart Cities
Published in English	Dominant language in publications

The papers were retrieved from the Scopus database using the following string:

(TITLE ("Smart City")) AND NOT (ALL ("DDos" OR "cyberattack" OR "cyber-attack" OR "Cryptography" OR "Security Of Data" OR "Network Security")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT TO (DOCTYPE, "ar"))

and it ends up with 1882 articles retrieved.

Inclusion criteria for patents have been reported in Table 3.

Table 3 Patents inclusion criteria

Inclusion Criteria	**Rationale**
Selection of patents without constraints on publication year	A large time window allows seeing the evolution of the topic
Search Field: Title, Abstract, and claims	These fields permit to identify the article focusing on Smart Cities

Patents were retrieved from the Orbit Intelligence database using the following string:

((Smart City) NOT (DDos OR cyberattack OR cyber-attack OR Cryptography OR (Security of Data) OR (Network Security)))/TI/AB/CLMS

resulting in 2277 patents retrieved.

The application of SLR i.e. the first step of SLNA-P allows to identify 1888 papers and 2277 patents.

3.4. Basic and Advanced Statistics for papers and patents

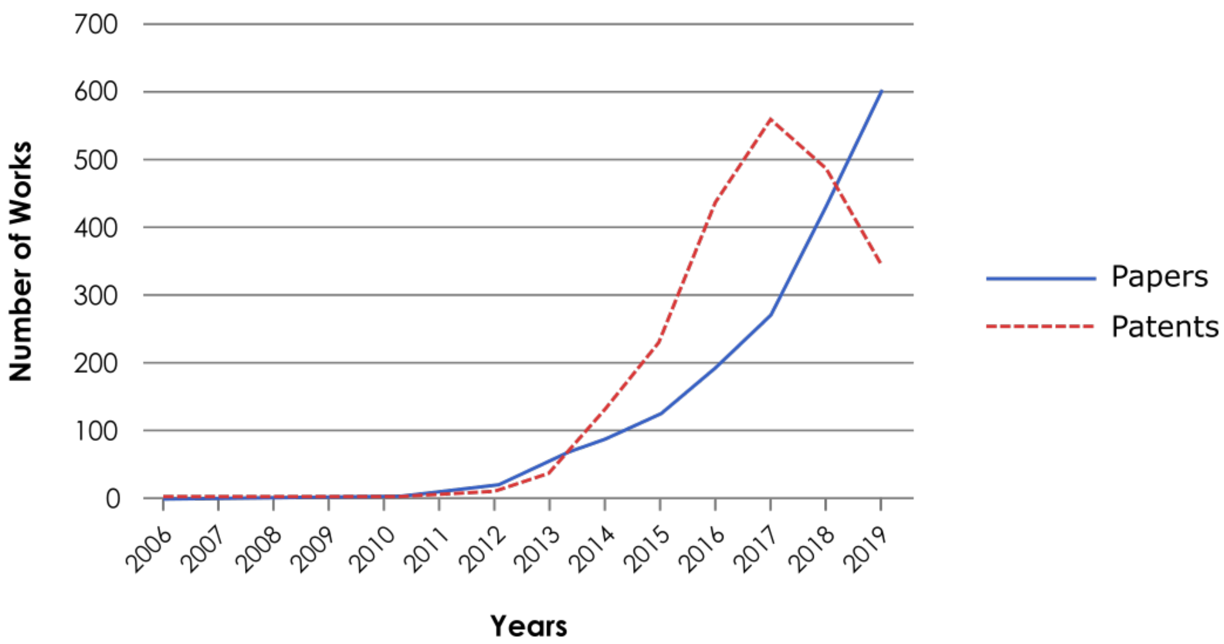
The basic statistic consists in analysing the temporal evolution of patents and papers to grasp the impact of the field and see how the areas of study are evolving over the years.

Advanced statistics consist in the application of the Burst detection algorithm provides (Kleinberg, 2003). In Figures 5-6 the reader can see the application of the Burst detection algorithm.

3.4.1. Production Evolution of papers and patents

From a static perspective, considering the publication year of the paper or the filing year of the patents, as shown in Figure 2, it is possible to note that starting from 2008 to 2011 (the years of the first competition launched by IBM on SC) the number of articles as well as the number of patents is increasing, so the area is under expansion. IBM started to regularly organise SC competition giving premium to the smarter cities. In 2011 IBM named 24 cities as SCs winners from 200 applicants. Nevertheless, the number of patents is increasing more rapidly than that of papers (from 2018 the patents are not complete because of the 18 months of blindness that patents need to be published).

Figure 2 Distribution of Papers and Patents during the years



3.4.2. Field Evolution of papers and patents

In terms of different fields, in Figure 3 and Figure 4, it is possible to notice the evolution over time of both papers and patents in terms of publications or filed patents. The most relevant fields in studying SC from a scientific point of view are computer science and engineering. In the last years, more papers studied the SC from a Business and management point of view. Patent technical fields shift from IT methods for management to telecommunication or digital communication.

Figure 3 Variation of Smart Cities-related publications journal fields over time (based on Scopus Categories)

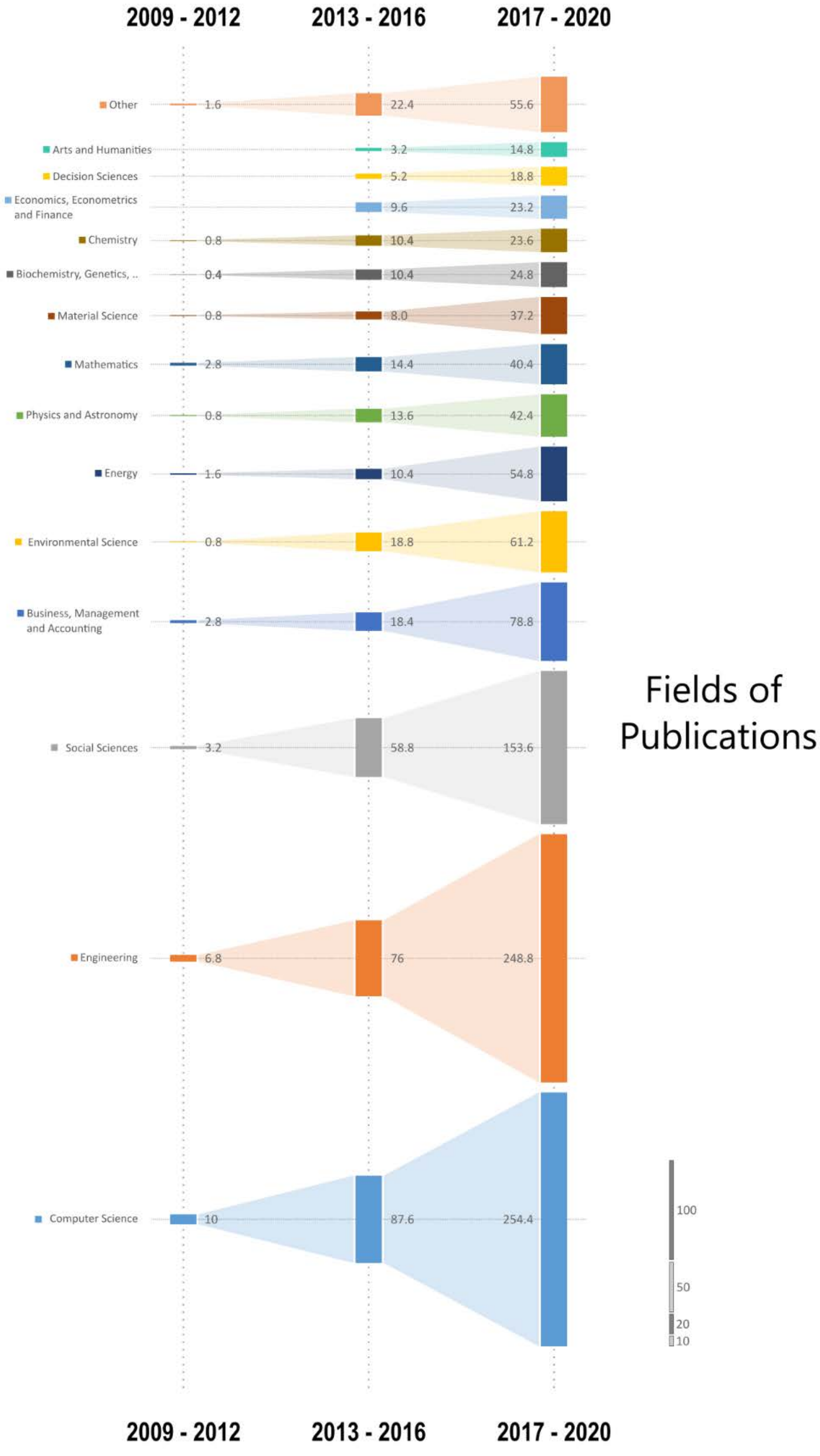
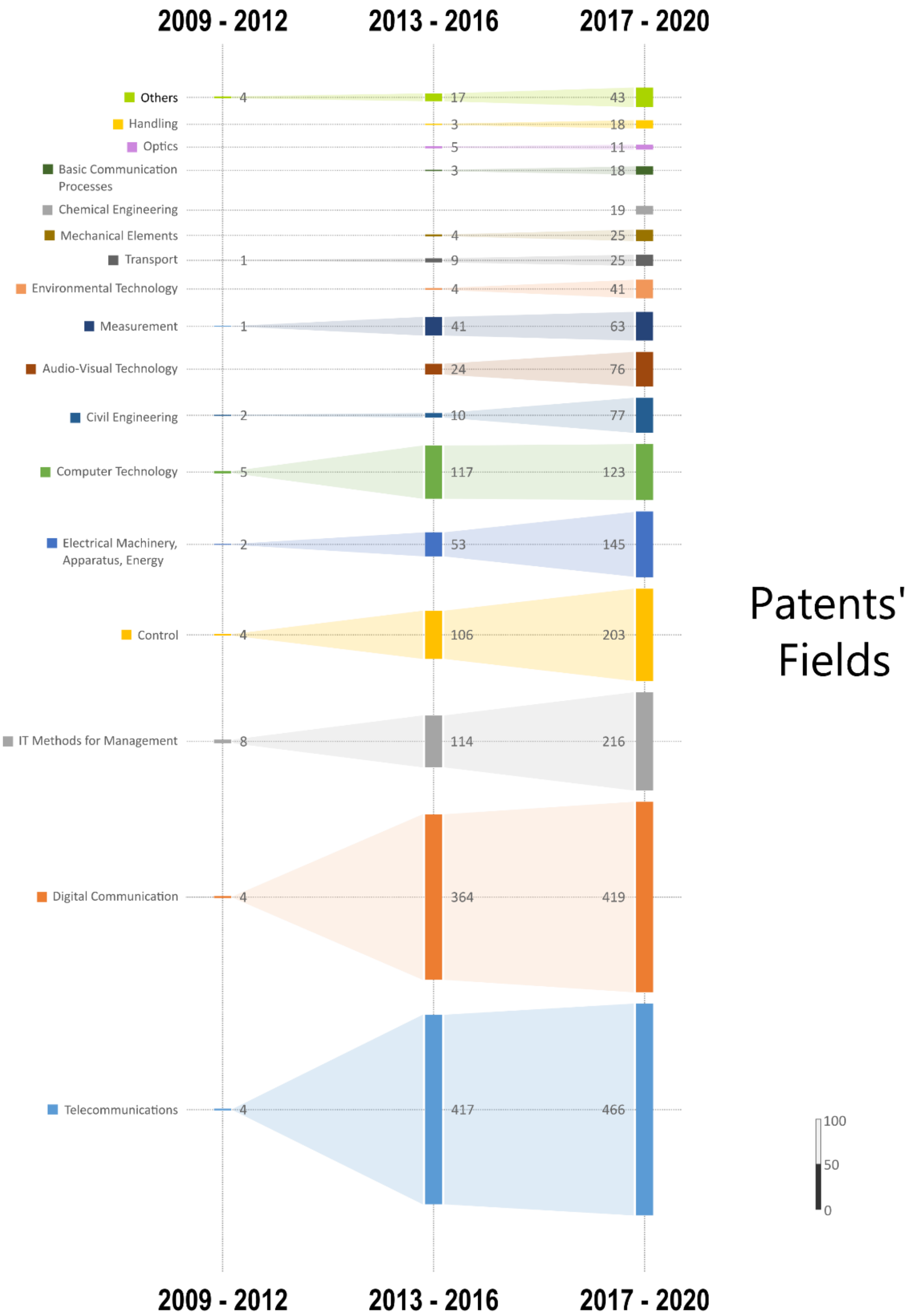


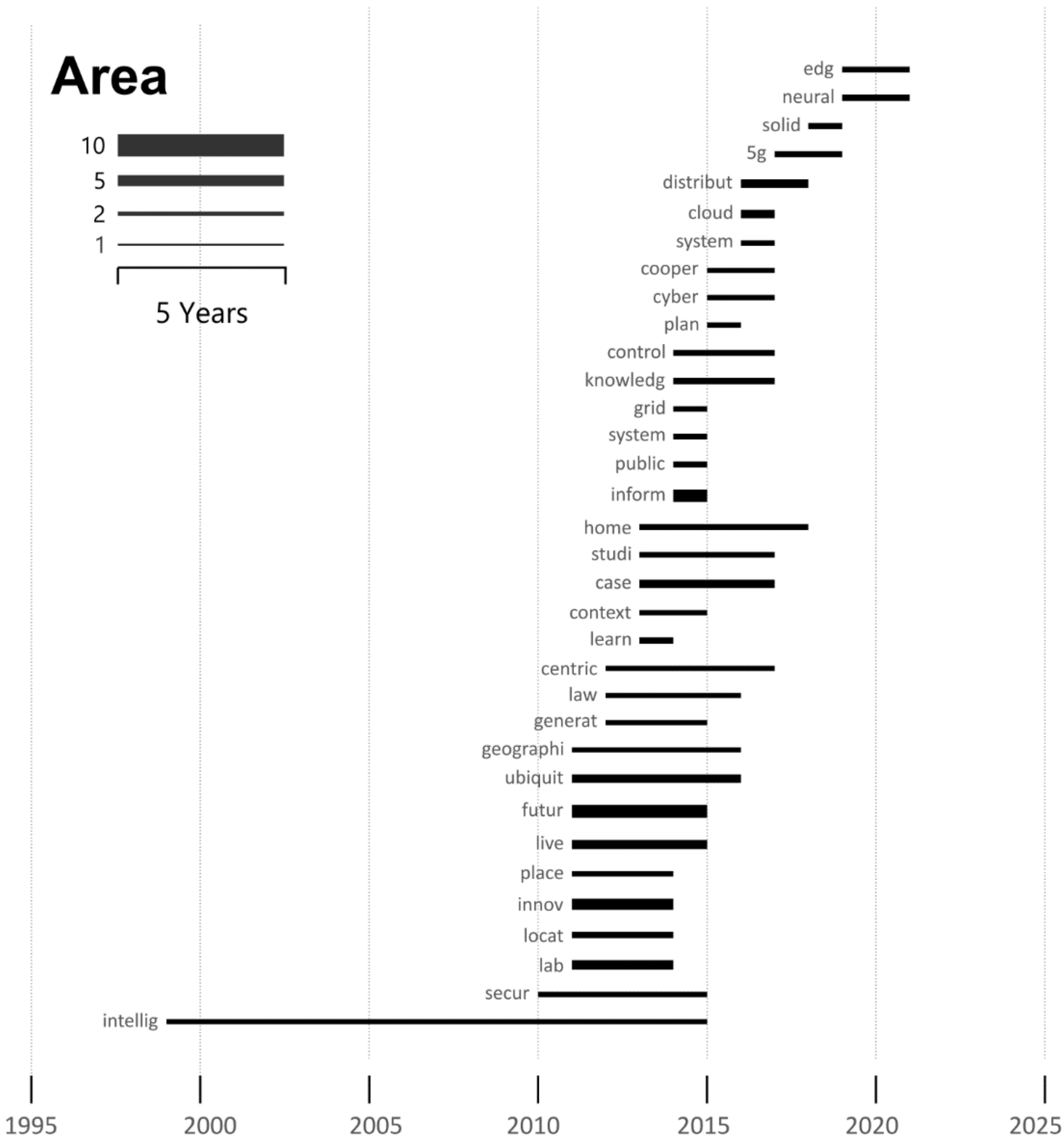
Figure 4 Patents fields' evolution in the years 2009-12, 2013-16 and 2017-2020
(Orbit Categories)



3.4.3. Burst detection of papers and patens

The output of peer-reviewed papers burst detection is shown in Figure 5.

Figure 5 Burst detection of papers authors' keywords.
The area of each Bar encodes a numerical attribute value, e.g. total amount of occurrences.



The oldest burst occurs in 2010 and 2011 and concerns concepts such as security, location, place, and geography. These are the years of the Yokohoma Digital City Project where the first masterplan for an SC was established and then of the 1st City Expo World in Barcelona called "Smart Society for Innovative and Sustainable Cities" which was the first event using the SC word.

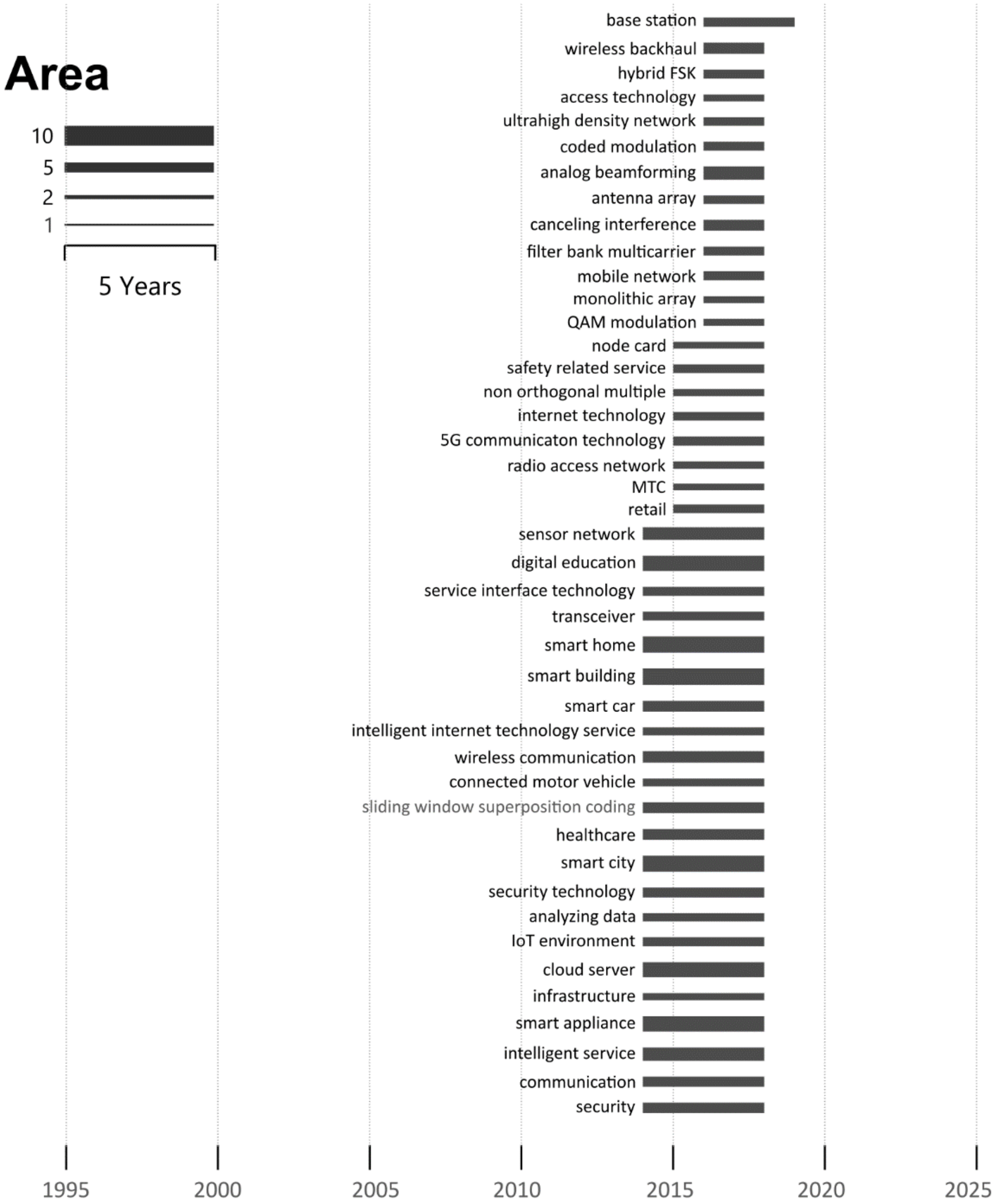
Since 2013, bursts refer to *learning, home, and case studies*. This suggests that the focus has been mainly on the home context. Moreover, the words *case* and *study* suggest the use of new methodologies, probably more linked to the management and social aspects. The word *learning* refers to the formalised way of teaching offered with the help of electronic resources.

Since 2014 *public, grid and control* are the main burst words. It suggests the involvement of more actors and stakeholders due to the need to cooperate among different institutions.

Since 2015, the burst plot refers to novel technologies such as *cloud, 5G, neural,* and *edge.* These words highlight the need for SC of having several enabling technologies for transferring and managing data. The bursts related to 5G technologies continue until 2019 with the keywords *beamforming* and *edg (for edge computing)*.

The burst detection of patents shows the appearance of patents' technical concepts along a timeline as represented in Figure 6.

Figure 6 Burst occurrence of patents technical concepts.
The area of each Bar encodes a numerical attribute value, e.g. total amount of occurrences.



The topics are strongly concentrated in the last years. From 2014 to 2018 the majority of bursts appear. The first patent topics regard technologies like IoT and sensors, data analysis, cloud, and wireless. All technologies that, as stated in the previous sections, are the core aspects in terms of ICT implementation of the SC. Moreover, they also look at the SC application of technologies, such as *smart home, smart appliances, healthcare, digital education, vehicle,* and *infrastructure.*

More recently, patents' technical concepts focus on newer technologies, particularly concerning 5G communication aspects. This emerges from the keywords *analog beamforming, antenna,* and *wireless communication.*

3.5. Network Analysis

3.5.1. Citation Network Analysis (CNA): Paper and patens Main Paths

CNA is a set of tools to study Citation Networks. Citation Networks are networks where the nodes are papers and the link represents the citations. Using these networks, it is possible to extract pieces of information on the flow of knowledge. Given two documents A and B where A is older than be, an Arrow from A to B means that B is citing A, and then there is a flow of knowledge from A to B. The Main Path tool (De Nooy et al., 2011; Lucio-Arias and Leydesdorff, 2008) allows extracting a backbone from citations that represent the documents that allow the development of the fields.

3.5.1.1.Main Path of Papers

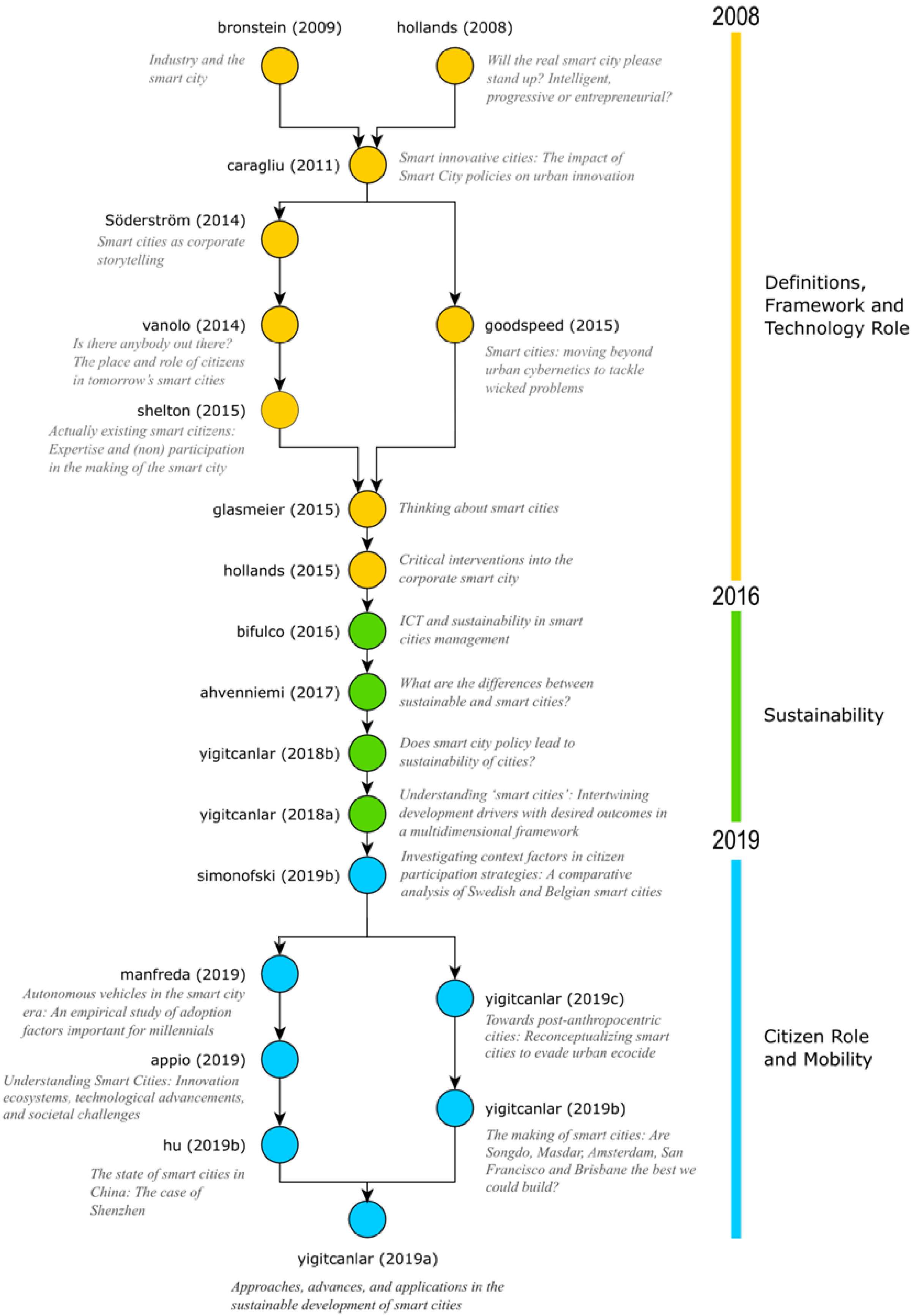
In the network of 1882 nodes/papers, one connected component emerged. Its main path has been extracted as shown in Figure 7.

From 2008 to 2015, the focus has been on **defining and conceptualizing the SC**. Hollands (2008) debates the future of urban development in Western countries concerning SC. Then, Bronstein (2009) stresses the fundamental role of the industry in developing the SC. Caragliu et al. (2011) shed light on the concept, by providing practical evidence on the geography of SC in Europe and looking at the factors determining its performance. Soderstrom et al. (2014) describe the evolution of the SC concept, by examining IBM's SC campaign. Vanolo (2014) analyses the concept of SC from a critical perspective, concentrating on the power/knowledge implications for the modern city. Shelton and Lodato (2015) suggest that attention should be paid to the "actually existing SC". They demonstrate the need to understand the effects of policies in actual cities. Goodspeed (2015) moves the definition of SC from the one of Cybernetic City, stressing the role of stakeholders. Also, Glasmeier and Christopherson (2015) explore the gap that exists between theory and practice, suggesting SC vendors to focus on collecting data about urban living through citizens and democratic forms of government than only on outcomes. Hollands (2015) critiques the growing trend toward corporate and entrepreneurial governance. He conceives the fact that the SC cannot only be based on technologies but multiple perspectives should be included to solve bigger problems such as poverty or environmental problems.

The second branch that started in 2016 focuses on the **sustainability** concept and on how it can be embodied in the SC paradigm. Bifulco et al. (2016) are concerned about the connection between SC ICT and sustainability and show how ICT and sustainability should be seen as a means to enable and empower the '*smartization*' process. Ahvenniemi et al. (2017) discover how the focus was stronger on modern technologies and "smartness" than on urban sustainability frameworks. Thus, they coin the term "smart sustainable cities", suggesting the need of redefining the SC concept and indicators that measure the contribution towards environmental, economic or social sustainability goals. Yigitcanlar and Kamruzzaman (2018b) investigate SC practices to understand their impact on achieving sustainable urban outcomes, revealing that 'smart' does not mean sustainable. Following that, Yigitcanlar et al. (2018a) suggest identifying and connecting each key driver to desired outcomes and then intertwining them in a multidimensional framework.

The third branch concerns the **role of the citizen.** Simonofski (2019) discusses citizen involvement. Yigitcanlar et al. (2019c) provide a retrospective view of the SC concept and rhetorically ask about the need for a post-anthropocentric urban turnaround, where stakeholders such as scholars, designers, and activists should be able to convince urban policymakers and the general public of the need. Then, Yigitcanlar et al. (2019b) develop a framework to support municipalities and administrations in understanding the big picture of this urban development to tackle urban prosperity, liveability, and sustainability matters. Hu et al. (2019) call for an institutional adaptation, and the attention to social and environmental problems. Then, Appio et al. (2019) aim to build a comprehensive overview of the topic by sketching a research agenda for scholars, practitioners, and policymakers. Manfreda et al. (2019) study the digital transformation and how it affects primarily citizens and then several areas such as transport, energy, government, and environment. In the end, Yigitcanlar et al. (2019a) offer a critical review concerning also the stakeholders' role regarding approaches, advances, and applications in the sustainable development of SC.

Figure 7 Main path of the main connected component of the paper citation network.
The main path ranges from 2008 to 2019. Three different branches can be distinguished.



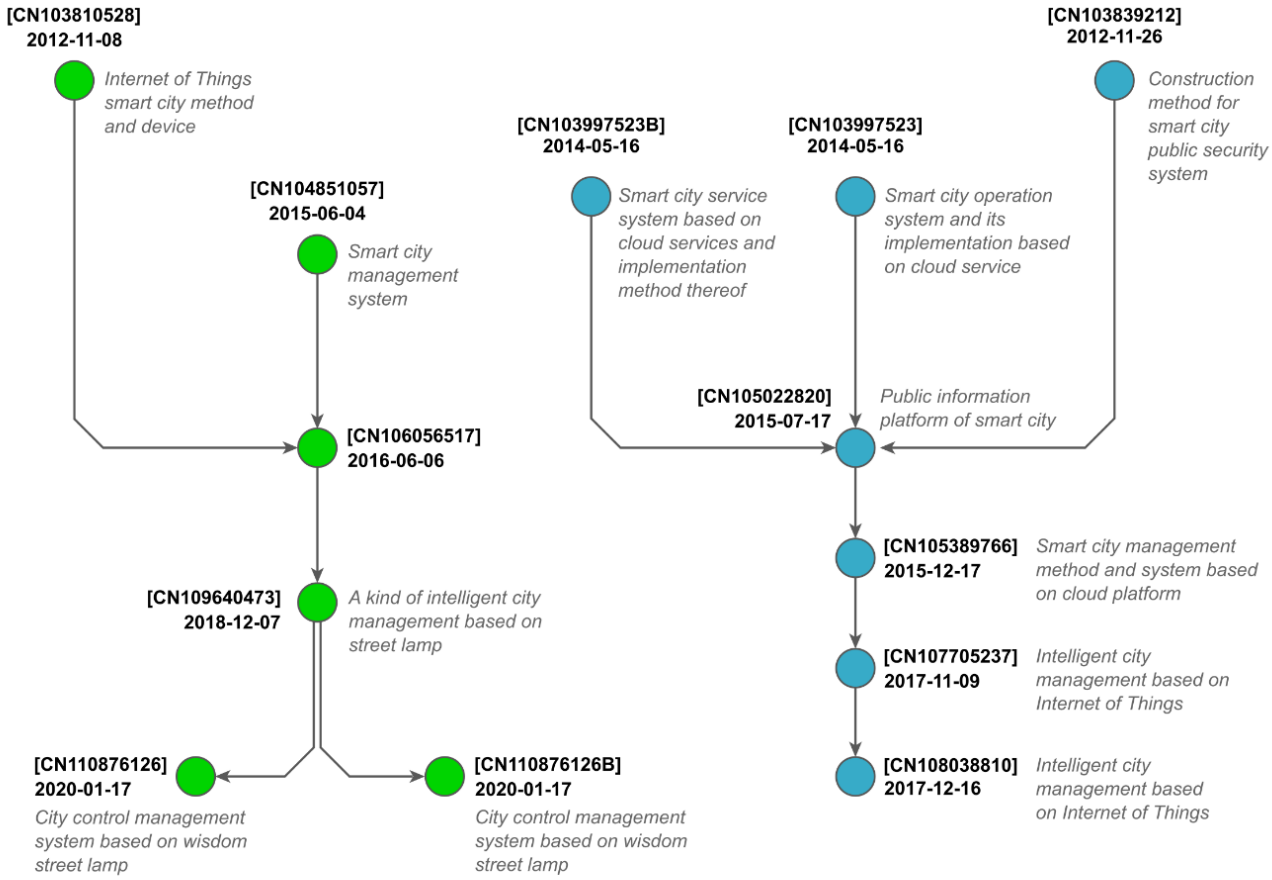
3.5.1.2. Main Path of Patents

The patent citation network has been built following the concept of a simple patent family, i.e., patents that share the same technical concept. Continuations and divisions that cover the same technical content belong to the same patent family, regardless of the priorities claimed[4]. Each node, in this case, represents a patent family. Different connected components have been extracted.

The main path of the first connected component concerns the management of the SC (Figure 8), based on cloud or IoT technologies. Some methods studied in this component are based on cloud services and allow establishing rapidly the application systems of SCs and the communication between applications and internal systems of enterprises. Patents develop SC public security systems and public information platforms that integrate a series of application platforms for enhancing various information sharing efficiency services, video resources, spatial geographic information, and thematic data converge to an information center and unified. Other intelligent city management systems are based on IoT. Also, in this case, they comprise technologies to monitor the city in real-time including a video camera, card reader, wireless communication module, etc. The city supervision center includes screen memory, wireless repeater, etc. The most recent advances study the interconnection and intercommunication of multiple platforms using intelligent street lamps. Thus, SC lamps will have a plurality of network functions such as intelligent illumination, traffic management, environmental monitoring, etc. Most of the patents are based in China whereas the EC Horizon 2020-funded Sharing Cities project promoted implementations of Smart lampposts with pilot projects in European Cities[5].

[4] epo.org/searching-for-patents/helpful-resources/first-time-here/patent-families.html
[5] https://nws.eurocities.eu/MediaShell/media/2020_Booklets_Lamppost_Final2.pdf

Figure 8 Main path of the first connected component: management of the SC.
Colours represent the main path alternative components.

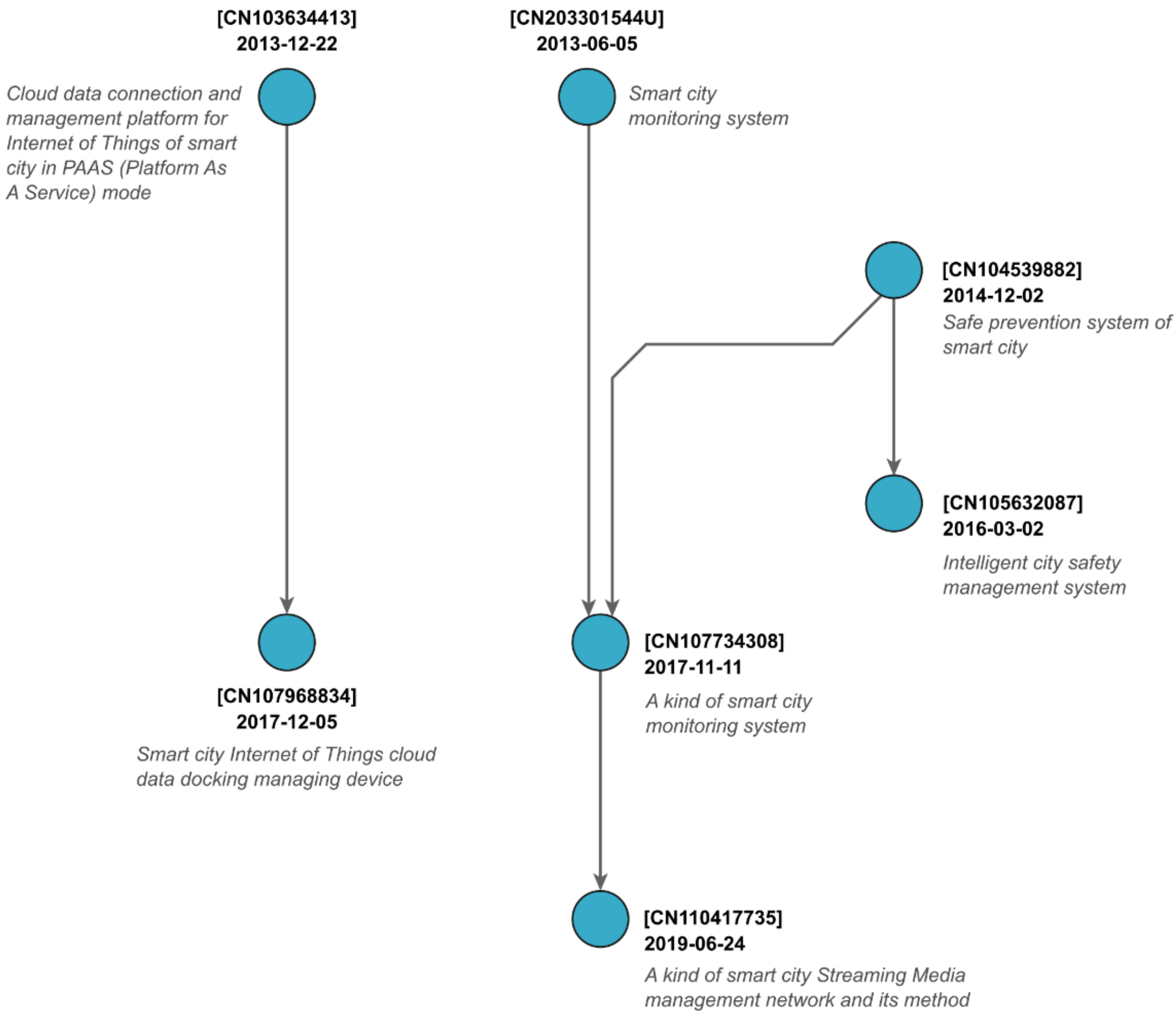


The main path of the second connected component (Figure 9) regards SC control, monitoring, and safety system. Also, in this case, cloud or IoT technologies are the main pillars. In the initial stages, inventions deal with SC monitoring systems and streaming media management networks. They include multiple video acquisition systems and an SC platform for distribution in different regions of the city. The system can retrieve data through information islands, reduce information interlayer, and realize unified monitoring, management, and resource allocation.

Still, on the subject of monitoring technologies, inventions focus on safety prevention systems of SC. They comprise weather monitoring systems, traffic control systemsor wireless connections. They aim to have a unified control, monitoring, management and allocation in order to use city resources and realize collaborative operation, reducing loss of manpower and material resources.

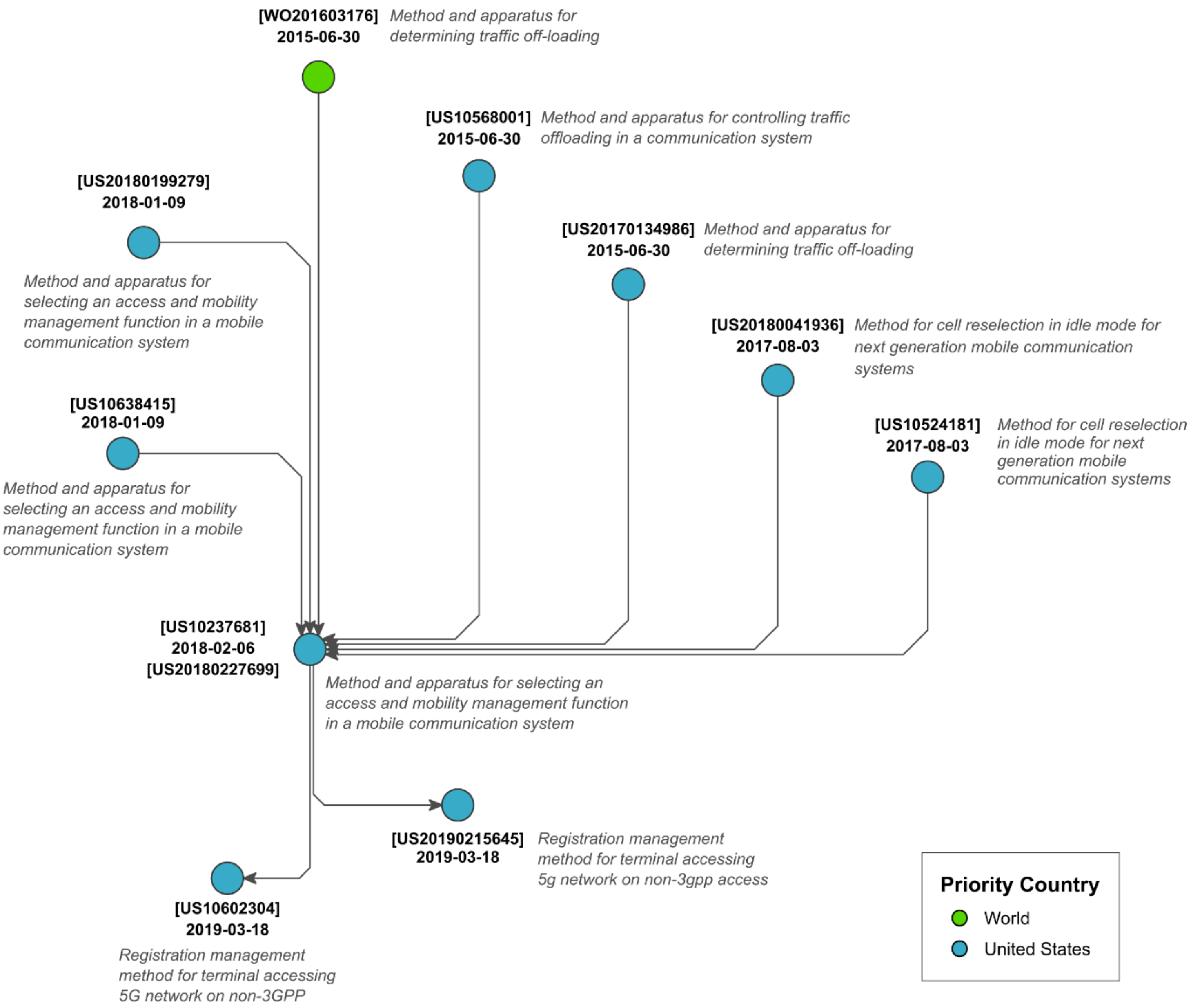
Other innovations focus on cloud data connection and management platforms for an IoT of a SC in a PAAS (Platform As A Service) model and in providing SCs IoT cloud data to dock managing device. Most of the patents are based in China.

Figure 9 Main path of the second connected component: control, monitoring and safety system of SC.



The main path of the third connected component concerns the communication systems and fifth-generation (5G) with a great focus on mobility communication. The main path (Figure 10) focuses on communication techniques that aim to merge a 5G communication for providing a higher data transmission rate beyond a fourth-generation (4G) system along with IoT technologies. These are innovations that may be applied in several different intelligent services such as smart home, smart building, health care, etc. The patents in the main path concern studies of methods for a registration state for accessing 5G network on non-3GPP access, for controlling or determining traffic offloading in a communication system, for cell reselection in idle mode for next-generation mobile communication systems, for selecting an access, and for the mobility management function in a mobile communication system. Most of the patents originate from the USA and it is a recently developed component (2018-2019).

Figure 10 Main path of the third connected component: control, monitoring and safety system of SC.



From the fourth connected component, the main paths detected are small; for this reason, no main path has been extracted.

The fourth connected component regards the channel state information reference signal (CSI-RS). This estimates the channel and reports channel quality information to the base station. These apparatuses are technologies based on equipment used by users which include a transceiver and a processor connected to the transceiver. Most of the patents are based in the USA.

The fifth connected component regards the communication channel and signals. Radio link, multiple reference signals and wireless communication systems are the main technological pillars involved in this component. The patents deal with methods and apparatus for handling radio link failure in systems using multiple reference signals or for performing radio link monitoring in a wireless communication system. The focus is on communication methods and systems for merging 5G communication systems with IoT technology and supporting a higher data transmission rate after the 4G system. Most of the patents are based in the USA.

The sixth connected component regards the mobile communication system, also including wireless ones. Patents implement methods and apparatus for performing paging in a mobile communication system, for inactive mode operation in a wireless communication system. Great emphasis is posed on communication methods and systems to merge a 5G communication system for supporting higher data rates beyond a 4G system with a technology for IoT. Most of the patents are based in the USA.

3.5.2. Concept Networks of papers and patents

The concept network are networks where the nodes are the concepts and the links express the fact that two concept appear together in the same documents. If two concepts appeared in ten documents together, they will be connected by a link with a weight of ten. The concepts considered in this works have been author's keywords for papers and technical concepts for patents since they better represent the contents of the documents.

3.5.2.1.Concept Networks for papers: Author's keywords networks

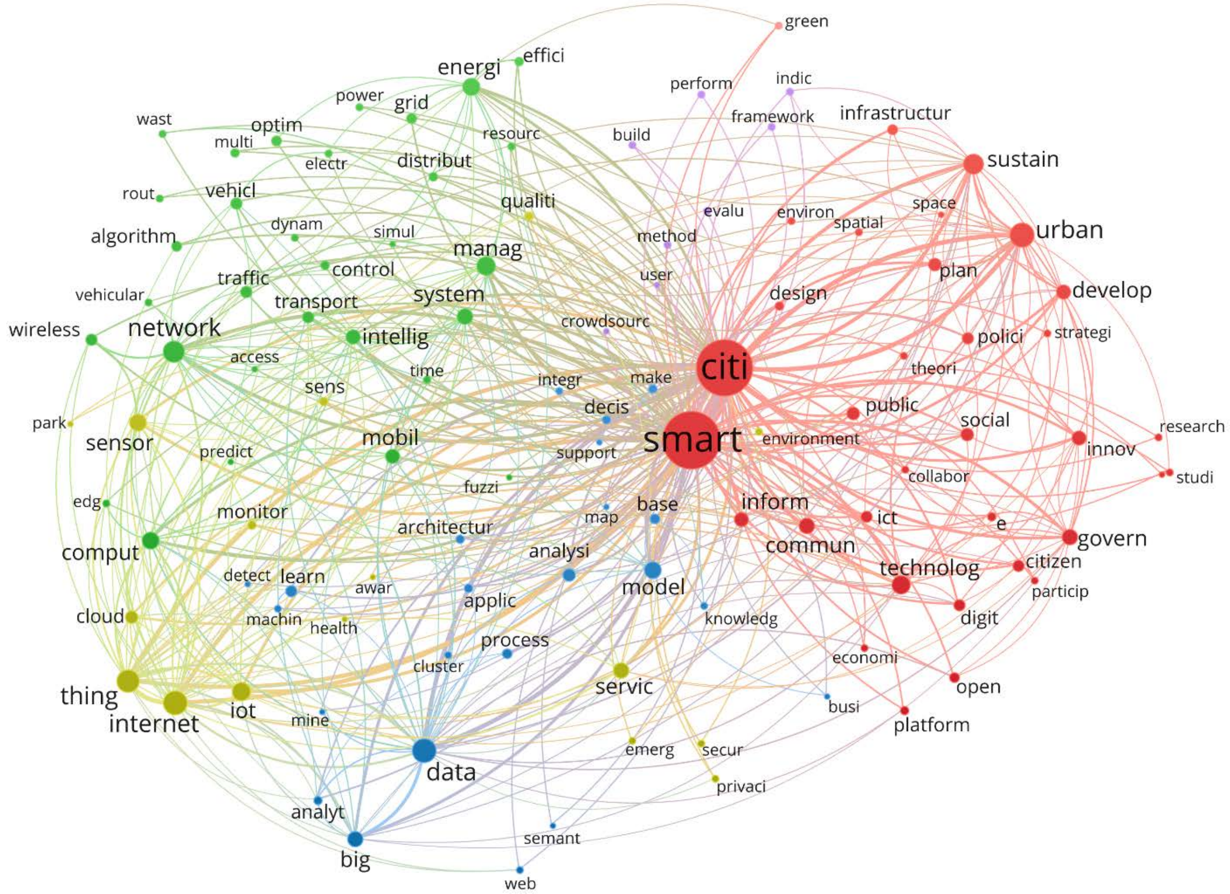
The keyword network that permits to study the co-occurrence of papers Author's keywords is shown in Figure 11. Five different clusters emerge.

- Cluster 1: Smart Living and Sustainability

The cluster deals with concepts such as urban planning, sustainability, quality of life and citizen participation. Citizen engagement is fundamental to achieve a sustainable and inclusive urban development. Environmental sustainability requires a comprehensive intervention policy and citizens' participation to increase the probability of success (Corsini et al., 2019). Critical observations have seen the SC as a "top-down" tendency to serve the interests of corporate and political actors, without the overlap of "bottom-up" approaches (Cowley and Caprotti, 2019). Smart community implementation processes need a common and shared vision of social innovation owned by multiple stakeholders that may have conflicting values (Chatfield et al., 2016). The social aspect is inextricably intertwined in the transition process (Walters, 2011; Corsini et al., 2019).

Consequently, addressing urban sustainability challenges and user participation requires changes in how systems and services are designed, organised and delivered (Zvolskaet al., 2019) using the citizen point of view (Belanche et al., 2016). Smart and sustainable cities should be a sort of distributed governance that merge environments, technologies, and ways of life, where the citizen is an active player (Gabrys, 2014).

Figure 11 Co-occurrence network of papers authors' keywords



- Cluster 2: Urban Mobility, Transport and intelligent networks

This cluster concerns the area of mobility and transport. This is corroborated by the words *intelligence, transport, traffic* and *mobile*. The increasing population mobility has led to a rapid increase of vehicles, which generates several challenges for road traffic management issues (Alsarhan et al., 2018; Paricio and Lopez-Carmona, 2019) and sustainability issues (Pinna et al., 2017; Zawieska et al., 2018). The main ICT challenge regards collecting massive data from multiple data sources involved in mobility areas and transmitting them to the control units for their analysis (Naseer et al., 2019).

The use of mobile phone data provides an important source and they are a key tool for enhancing urban planning and reducing inefficiencies in cities (Steenbruggen et al., 2015). During the COVID-19 pandemic, data from mobile phones provided valuable insights on citizen mobility offering valuable information on the definition of prevention strategies and understanding the efficacy of lockdown and movement restrictions (Vincenti et al., 2020). Sensor-based devices are developed for different applications to collect a massive amount of data for exploiting IoT paradigm and mobile vehicles can support the widespread of code with an opportunistic communication style (Teng et al., 2019) also as an energy-efficient alternative to accommodate and disseminate data (Naseer et al., 2019).

- Cluster 3: data analytics

This cluster focuses on the advanced techniques to manage and analyse a massive amount of data. This is suggested by the words *big, data, learning, model and analytics.* Undeniably a city evolves into a SC with the help of the latest ICT and IoT. SCs are built on top of large-scale, using IoT systems that are experiencing rapid growth in particular in terms of the use of sensors (You et al., 2019; Estrada et al., 2020). As result, a huge amount of data generated must be processed timely, accurately and using efficient methods (Dutta et al., 2019; Malik et al., 2018). Machine Learning (ML) and Deep Learning (DL) are one of the main technologies to leverage IoT and Big Data, also because they help in forecasting future states (Habibzadeh et al., 2019). Habibzadeh et al. (2019) present a multi-faceted survey of machine intelligence in modern implementations, others show the implementation of those systems (Huang and Kuo, 2018; Malik et al., 2018; Mohammadi et al., 2018; Dutta et al., 2019; Estrada et al., 2019).

- Cluster 4: data collection, IoT and Sensors

This cluster focuses on the data collection technologies regarding essentially IoT and, consequently, sensors. IoT has been identified as a revolutionary technology that is empowering SC and finds application mostly in all SC domains (Liu et al., 2020). The growth of Big Data and IoT technologies enable cities to obtain valuable intelligence from massive real-time in a short period (Nasiri et al., 2019). After the confluence of IoT and cloud computing paradigms, sensor networks are used in several places, growing in number and significance (Calderoni et al., 2019). One of the main concerns regards the provision of versatile and robust frameworks able to store and reorganise data collected by sensors as well as privacy and security complexity (Toma et al., 2019; Gheisari and Wang, 2020; Ahlgren et al., 2016; An et al., 2019). The collection of this massive amount of data requires high levels of energy consumption (Sun et al., 2018).

The latest advances regard the Internet of Everything (IoE) that will allow rethinking the SC, the Internet of Robotic Things (IoRT), that aims to bring together autonomous robotic systems (Liu et al., 2020), and the collaborative Internet of Things (C-IoT) that involves many communities (Montori et al., 2018). IoT should be linked with several methodologies previously mentioned, such as ML, Artificial Intelligence (AI) (Chatterjee et al., 2018; Liu et al., 2020), cloud computing (Jin et al., 2014; Sun et al., 2019) or fog computing (Tang et al., 2017).

IoT is used to enhance sustainability and energy optimization and security (Sundhari and Jaikumar, 2020; Brundu et al., 2017; Park et al., 2018). It is used in smart buildings (Sundhari and Jaikumar, 2020), for waste management (Cerchecci et al., 2018) or environmental issues (Toma et al., 2019). In the mobility and transport areas, the development of urban centres has brought several challenges for traffic load, management and IoT represent one piece to solve this problem.

Smart visual sensors have been studied (Barthélemy et al., 2019) and some others were concerned about the use of IoT for sustainable forms of transport (Behrendt, 2019) safety conditions (Badii et al., 2019) urban environment efficiency (Anjomshoaa et al., 2018).

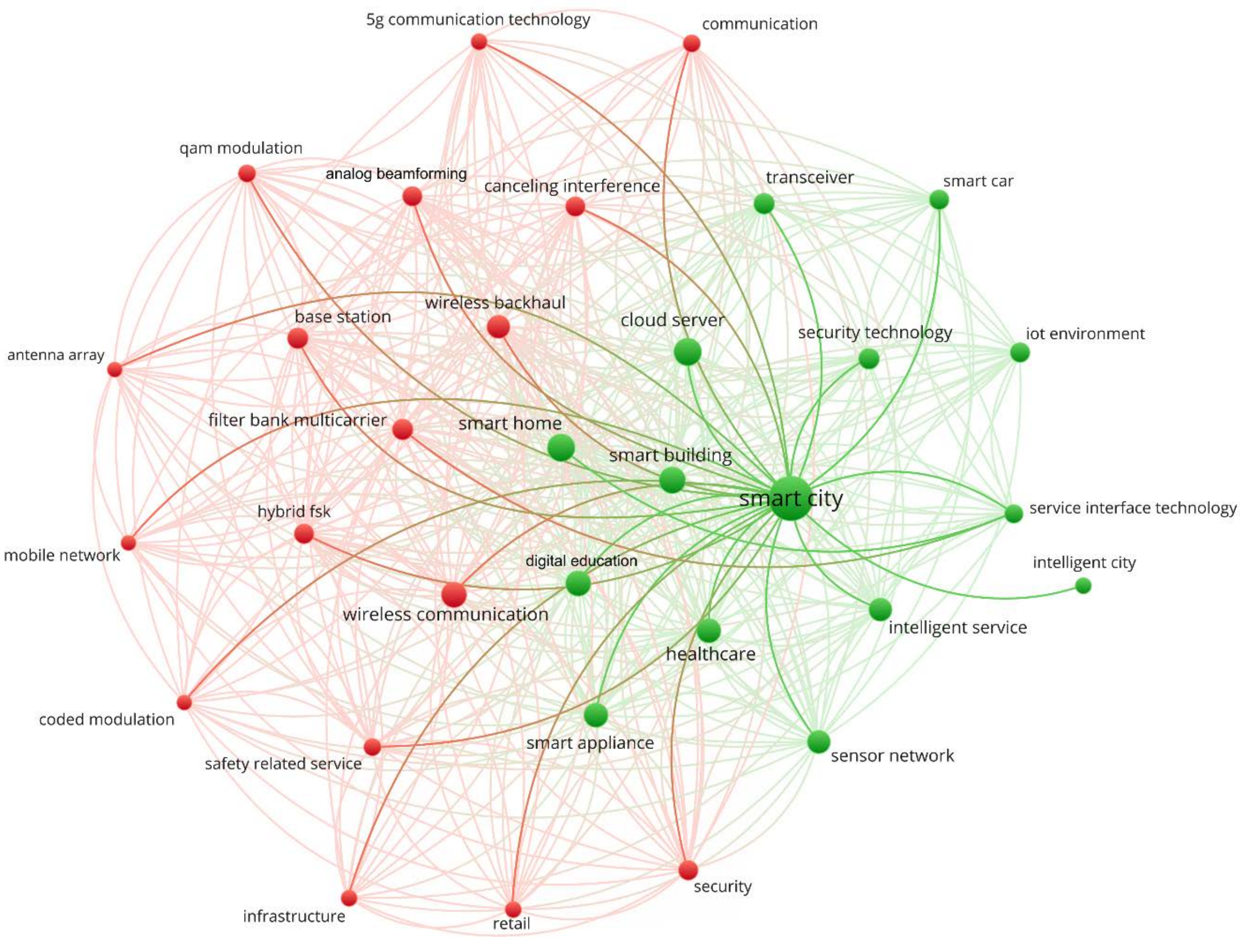
- Cluster 5: Crowdsourcing and performance evaluation

This cluster focuses on the analysis of SC performance assessment and the crowd involvement role in enhancing SC performance. This is observable by the words *performanc, evaluat, framework*, *crowdfunding*. Studies focus on methodologies to assess the SC progress towards defined targets and several evaluation approaches have been developed. Nevertheless, they are often limited only to the technological and "smartness" aspects and direct and indirect effects of SC on urban performances have not yet been quantified comprehensively (Castelnovo et al., 2016; Nicolas et al., 2020). Ahvenniemi et al. (2017) show that the focus was on modern technologies and "smartness" instead of on urban sustainability frameworks. The cluster focuses on crowd participation in terms of user-driven approach and contribution as a source of data (Breetzke and Flowerday, 2016). In terms of crowdsourcing, after Schuurman et al. (2012) that detail the strengths and weaknesses of crowdsourcing for idea generation and idea selection in SC, Li et al. (2019) investigate the motives driving people's willingness to use a mobile crowdsourcing app, a main source of information for SC, to voluntarily help others (Zhang et al., 2018), Prandi et al. (2017) study a way to collect data from crowdsourcing and crowdsensing to map urban and architectural accessibility to help people with disabilities, Lee et al. (2017) analyse the needs motivating crowdsourcing participation in SC projects, Papadopoulou and Giaoutzi (2019) investigate crowdsourcing and, so-called, *living labs* to SCs development, Semanjski and Gautama (2015) explore the applicability of crowdsourced on mobility management and citizen overall quality of life in cities.

3.5.2.2.Concept network for patents: the technical concept networks

The patents' technical concepts show two distinct clusters as shown in Figure 12.

Figure 12 Co-occurrence of patents major technical concepts



- Cluster 1: Communication technologies

This cluster focuses on technologies such as antenna, internet and wireless communication. Patents belonging to this cluster have been issued as priority in China or South Korea. The patents address methods and apparatus for communication mainly based on wireless and mobile. Older technologies innovate on antennas, developing, for example, electronic devices including a cover having antenna module or antenna beam tracking.

There is a set of patents focalized on method and apparatus for implementing wireless systems, including also, patents regarding the assignment of resources, decoding data, uplink data transmission, channel transmission, transmitting and receiving control and data channels in wireless communication, reporting maximum transmission power, determining path loss in a wireless communication system, and operating multiple bandwidth part. More recently, the focus has also been on 5G technologies.

Other patents concern the broader field of mobile communication systems, studying methods and apparatus for transmitting scheduling requests, transmitting and receiving paging messages, performing contention-based and non-contention-based beam failure recovery, generating and transmitting channel feedback in a mobile communication system employing two-dimensional antenna array and the broadband system.

More recently, patents are focusing also on the application of wireless systems to specific contexts, such as environmental sanitation management systems, remote medical rehabilitation, autonomous vehicles power pipe or smart home, etc.

- Cluster 2: IoT environment and Cloud Technologies

The second cluster focuses on sensor networks technologies and cloud technologies, as suggested by words *cloud services* or *IoT environment*, and their application, as suggested by the words *smart home* or *smart car*. The cluster is related to technologies developed in the USA and South Korea. Novel tools, protocols and techniques are provided for implementing "IoT", following the fact that computing systems or IoT management node receives data from sensors and consequently several different actions may be taken for different contexts (e.g., household devices; vehicular or roadway). These technologies may be effective only related to mobile communication, for example linking cloud and wireless.

Patents in this cluster concern several aspects of the SC, such as mobility. Patents study parking methods for management systems or methods for authenticating vehicle smart key or systems. Another focus is on infrastructures and homes, for example, the development of the smart power grid that applies big data systems, the development of techniques and systems to control the room temperature and humidity or the street-lamps as tools to manage some management systems of the SC. The last area concerns human well-being, in terms of healthcare and apparatus for wearable and smart devices.

5. Discussion

The areas identified in research and/or technology are ICT, Mobility, Living and People and sustainability. For each area, science and technology research is analysed using the SLNA tools. The main results of this paper are outlined in Table 4.

ICT-related topic has been the main area of interest covered by both publications and patents**.** High interest has been reached by data acquisition, data analysis and then communication topics. SC has made use of several ICT technologies, ranging from 4G or internet to more breakthrough technologies such as 5G, Big data and IoT. The most recent advances regard the IoE, C-IoT, AI, ML and edge computing. IoT has provided the biggest opportunities to cities for capturing huge, real-time and diversified data from different sensors, that can be used to refine the quality of SC (Gupta et al., 2019; You et al., 2019; Estrada et al., 2019; Liu et al., 2020). However, versatile and robust frameworks need to be developed to store and reorganise data collected by sensors; advanced techniques should be studied and developed to manage and analyse data quickly, efficiently and accurately (Malik et al., 2018; Dutta et al., 2019;). Patents are going in this direction, for example studying technologies to control the city through on wisdom street-lamp.

In terms of differences between science and applied technologies**,** the application fields show divergences. Both have focused on **Mobility**, but with slight differences between publications and patents. As also suggested by Gupta et al. (2019), probably because this is a field in which IoT can be simply embodied and several smart mobility applications have been studied (Quijano-Sánchez et al., 2020). They are very effective in decreasing stress on traffic, also lowering the consumption of resources and mitigating the consequences of climate change (Soomoro et al., 2018). Conversely, technology innovations have had a more extensive application. As suggested by the study on patents, the communication and IoT technology developed have been used in digital education, healthcare, smart home and building, retail**.**

Living and people are also becoming a main concern and topic of study for scientific publications, particularly related to citizens' quality of life. Citizens seem not to be an important actor in developing the technology yet (at least until the COVID-19 outbreak). Nevertheless, the probability of success of SC implementation increases with public engagement and acceptance (Corsini et al., 2019). Related to this, the other divergence arises: according to scientific publications, citizen engagement is fundamental to achieve a sustainable and inclusive urban development, proposing also a bottom-up approach to serve the interests of corporate and social-political actors (Hollands, 2008). Citizens should actively participate in the activities of city development and collaborate with multiple stakeholders. However, citizens' real desires and needs are not well known (Vanolo, 2016). Such a debate is discussed in the SC literature that claims that corporations exercise control over the current and future trend of development of the SCs (Townsend, 2013) and it is confirmed by looking at the technological production where big corporations play the main role and only barely involve other actors such as universities. In the technical production, the citizen is not mentioned but it is mainly used the concept of user of technologies. This is reflected in the governance aspects of the SC.

Many researchers are studying the role of governance and policy in SC development (Yigitcanlar et al., 2018a, Gupta et al., 2019), also concerning the effectiveness of public-private partnerships (Smigiel, 2019).

Therefore, a tension between establishing a centred provision of services and contemporaneously working actively and independently exists (Yigitcanlar and Kamruzzaman, 2019d). This should be mirrored in patents, but the path of development seems an independent work of several actors.

The other main difference regards the **Sustainability** aspect. Sustainability is probably one of the most critical global issues today. From a scientific point of view, it is one of the themes more widely assessed and Cowley and Caprotti (2019) claim the need to fill the gap between the practical motivations of SC initiatives and the already existing environmental/sustainable and social policies. In general, the smart initiatives aim at increasing energy efficiency, in new or old constructions, by incorporating technologies that allow increasing sustainability. A smart environment also includes actions to manage sustainably the city resources, such as air quality and waste. Differently sustainability or related words seem not to be embodied in technological innovations and they seem to not cope with the issue of resource scarcity.

Finally, in terms of **Living, People and Citizen Involvement**, a common and holistic system should be studied to measure the performance and standards. It is not a well-developed research theme and in terms of patents, we notice that only a few standards have been published except for the ones of Samsung. Under this theme, studies regard the SC monitoring systems (this slightly developed also in patents), SC ranking processes, successful performance of SCs, and framework to assess the SC performance (Castelnovo et al., 2016; Yoo et al., 2016; Ahvenniemi et al., 2017; Nicolas et al., 2020). Due also to the fragmented development, SC has to comply with several indicators (Kourtit et al., 2012) and refer to frameworks such as the SCs Wheel, where at least six areas must be concerned as defined in the Smart Cities Index[6]. They should be used not only to compare cities but also to evaluate their development to understand the direction taken (Giffinger and Pichler-Milanović, 2007). Subsequently, assessment systems related to the SC performance must be developed to measure the performance of cities (Lazaroiu and Roscia, 2012). Probably also the technologies developed should be created and conceived already to address such performance. The use of real-time data to retrieve and collect needed information contributing to the definition of related performance indicators of SCs will guarantee the success of the SC initiative (Marsal-Llacuna et al., 2015; Wang and Xu, 2015; Gupta et al., 2019). In this context, where information excesses, systems for information filters and synthesis could be developed (Marsal-Llacuna et al., 2015).

[6] https://www.imd.org/research-knowledge/reports/imd-smart-city-index-2019/

Table 4 Sum up of the research directions found according to the different tools and possible future researches

Area of Research: ICT		
Tools of Analysis	**Papers**	**Patents**
Burst Detection	Cloud, 5G, Edge	Wireless Backhault, 5G Communication Technology
Citation Network	*Hollands (2008), Bronstein (2009), Caragliu et al. (2011), Soderstrom et al. (2014), Vanolo (2014), Goodspeed (2015), Shelton and Lodato (2015), Glasmeier and Christopherson (2015), Hollands (2015)*	For example: **US10237681:** Registration management method for terminal accessing 5G network on non-3GPP access; **CN105389766:** Smart city management method and system based on cloud platform; **CN107705237:** Smart city management system based on IoT (Internet of Things)
Keyword Network	**Cluster 3:** data analytics **Cluster 4:** data collection, IoT and Sensors	**Cluster 1:** Communication technologies **Cluster 2:** IoT environment and Cloud Technologies
Future Directions: Technologies need to be integrated in the full SC framework and as emerged from patents they should probably be transversal for multiple domains		
Area of Research: Mobility		
Tools of Analysis	**Papers**	**Patents**
Burst Detection	Place, Location, Geograph	Smart Car

Citation Network	*Hu (2019), Appio et al. (2019), Manfreda et al. (2019)*	Study of technologies that may be applied for example to cars
Keyword Network	**Cluster 2:** Urban Mobility, Transport and intelligent networks	**Cluster 1:** Communication technologies **Cluster 2:** IoT environment and Cloud Technologies
Future Directions: Continuous studies on how to create an efficient and reliable mobility. Patents suggest a more transversal approach of different applications, i.e. not focusing on mobility, but also infrastructure, healthcare, retail, etc. The focus could also be on other SC areas, probably one of the most important at date can be the health aspect due to Covid-19 emergency.		
Area of Research: Sustainability		
Tools of Analysis	**Papers**	**Patents**
Burst Detection	Grid	-
Citation Network	*Bifulco et al. (2016), Ahvenniemi et al. (2017), Yigitcanlar (2018b),* *Yigitcanlar (2018a)*	-
Keyword Network	**Cluster 1:** Smart Living and Sustainability	**-**
Future Directions: Need to integrate the sustainability concept in the SC, measuring the impact Technologies should also concern about this aspect, thus still not a high number of patents realized sustainable SC innovations		

Area of Research: Living, People and Citizen Involvement		
Tools of Analysis	**Papers**	**Patents**
Burst Detection	Case Study	Digital Education
Citation Network	*Simonofski et al. (2019), Yigitcanlar et al. (2019c), Yigitcanlar et al. (2019b), Yigitcanlar et al. (2019a)*	-
Keyword Network	**Cluster 5:** Crowdsourcing and performance evaluation	**-**
Future Directions: Citizens are still seen as users from a technological point of view. Probably they should be integrated already in the design of the technology and in the realization of patent innovations.		

6. Conclusions

SCs have emerged as an area of growing interest in government, industry, and academia. Previous works mainly review scientific publications and often do not show a dynamic overview of the SC theme although its high activity is shown in terms of research interest. Moreover, technological production has been overlooked although it has been significant and intense. On this premise, this work analyzes both scientific publications and patents using the SLNA methodology. Based on the analysis of 1882 papers collected from Scopus and 2277 patents retrieved from Orbit, this paper shows a way to integrate different and fragmented perspectives, detailing the evolutionary pattern and emerging trends in SC.

The main areas identified were ICT, Mobility, Sustainability and Living, People and Citizen Involvement. The ICT perspective was considered both from the point of view of science and technology. On the contrary, Mobility and Living, People and Citizen Involvement were partially considered in the technological development whilst sustainability seems not considered by the technological development and it appeared more a prerogative of science.

This leads to several practical implications. SC development presents technical and social challenges for designers, managers, and citizens. SC implementation processes need a common and shared vision that merges multiple stakeholders' goals that may have also conflicting values (Chatfield et al., 2016). A common development should be proposed. The transition process is no longer a matter only of techno-economic innovations, but the social aspect is inextricably (Walters, 2011; Corsini et al., 2019). Addressing urban sustainability challenges and user participation requires changes in how systems and services are designed, organised and delivered (Zvolska et al., 2019). Smart and sustainable cities should have a sort of distributed governance that merges environments, technologies, and ways of life, where the citizen is an active player (Gabrys, 2014). The importance of the role of citizens as active players has become even more clear during the COVID-19 pandemic outbreak and probably stronger attention should be paid to the integration of citizens/patients in the SC. Thus, the full life of every citizen has been changed and some SC trends should be accelerated to monitor the pandemic diffusion according to the daily life of each citizen. To policy makers, this suggests the need for strong integration between all the parts, boosting collaborative environments that involve citizens, industries, politics, etc.

This work is not without limitations. Among others, we acknowledge the fact that open-source development is particularly relevant in the SC context. Papers and patents are probably two of the most important sources of data, but future studies should also concern open-source databases.

References

Ahlgren, B., Hidell, M. and Ngai, E.C.H., 2016. Internet of things for smart cities: Interoperability and open data. *IEEE Internet Computing*, *20*(6), pp.52-56. Ahmed, S., Shah, M. A., & Wakil, K. (2020), Blockchain as a Trust Builder in the Smart City Domain: A Systematic Literature Review. *IEEE Access*, 8, 92977-92985.

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I. and Airaksinen, M., 2017. What are the differences between sustainable and smart cities?. *Cities*, *60*, pp.234-245.

Ali, W., Frynas, J.G. and Mahmood, Z., 2017. Determinants of corporate social responsibility (CSR) disclosure in developed and developing countries: A literature review. *Corporate Social Responsibility and Environmental Management*, *24*(4), pp.273-294.

Almirall, E., Wareham, J., Ratti, C., Conesa, P., Bria, F., Gaviria, A. and Edmondson, A., 2016. Smart cities at the crossroads: New tensions in city transformation. *California Management Review*, *59*(1), pp.141-152.

Alsarhan, A., Al-Dubai, A.Y., Min, G., Zomaya, A.Y. and Bsoul, M., 2018. A new spectrum management scheme for road safety in smart cities. *IEEE Transactions on Intelligent Transportation Systems*, *19*(11), pp.3496-3506.

An, J., Le Gall, F., Kim, J., Yun, J., Hwang, J., Bauer, M., Zhao, M. and Song, J., 2019. Toward global IoT-enabled smart cities interworking using adaptive semantic adapter. *IEEE Internet of Things Journal*, *6*(3), pp.5753-5765.

Anjomshoaa, A., Duarte, F., Rennings, D., Matarazzo, T.J., deSouza, P. and Ratti, C., 2018. City scanner: Building and scheduling a mobile sensing platform for smart city services. *IEEE Internet of things Journal*, *5*(6), pp.4567-4579.

Appio, F.P., Lima, M. and Paroutis, S., 2019. Understanding Smart Cities: Innovation ecosystems, technological advancements, and societal challenges. *Technological Forecasting and Social Change*, *142*, pp.1-14.

Badii, C., Bellini, P., Difino, A. and Nesi, P., 2019. Sii-Mobility: An IoT/IoE architecture to enhance smart city mobility and transportation services. *Sensors*, *19*(1), p.1.

Baldini, G., Barboni, M., Bono, F., Delipetrev, B., Duch Brown, N., Fernandez Macias, E., Gkoumas, K., Joossens, E., Kalpaka, A., Nepelski, D., Nunes De Lima, M., Pagano, A., Prettico, G., Sanchez Martin, J., Sobolewski, M., Triaille, J., Tsakalidis, A. and Urzi Brancati, M., Digital Transformation in Transport, Construction, Energy, Government and Public Administration, Desruelle, P. editor(s), EUR 29782 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-08614-7, doi:10.2760/058696, JRC116179.

Barthélemy, J., Verstaevel, N., Forehead, H. and Perez, P., 2019. Edge-computing video analytics for real-time traffic monitoring in a smart city. *Sensors*, *19*(9), p.2048.

Behrendt, F., 2016. Why cycling matters for smart cities. Internet of bicycles for intelligent transport. *Journal of transport geography*, *56*, pp.157-164.

Behrendt, F., 2019. Cycling the smart and sustainable city: analyzing EC policy documents on internet of things, mobility and transport, and smart cities. *Sustainability*, *11*(3), p.763.

Belanche, D., Casaló, L.V. and Orús, C., 2016. City attachment and use of urban services: Benefits for smart cities. *Cities*, *50*, pp.75-81.

Bifulco, F., Tregua, M., Amitrano, C.C. and D'Auria, A., 2016. ICT and sustainability in smart cities management. *International Journal of Public Sector Management*.

Bokolo, A., 2021. Managing digital transformation of smart cities through enterprise architecture–a review and research agenda. *Enterprise Information Systems*, *15*(3), pp.299-331.

Breetzke, T. and Flowerday, S.V., 2016. The usability of IVRs for smart city crowdsourcing in developing cities. *The Electronic Journal of Information Systems in Developing Countries*, *73*(1), pp.1-14.

Brohi, S.N., Bamiah, M. and Brohi, M.N., 2018. Big data in smart cities: a systematic mapping review. *Journal of Engineering Science and Technology*, *13*(7), pp.2246-2270.

Bronstein, Z., 2009. Industry and the smart city. *Dissent*, *56*(3), pp.27-34.

Brundu, F.G., Patti, E., Osello, A., Del Giudice, M., Rapetti, N., Krylovskiy, A., Jahn, M., Verda, V., Guelpa, E., Rietto, L. and Acquaviva, A., 2016. IoT software infrastructure for energy management and simulation in smart cities. *IEEE Transactions on Industrial Informatics*, *13*(2), pp.832-840.

Buttazzoni, A., Veenhof, M. and Minaker, L., 2020. Smart city and high-tech urban interventions targeting human health: an equity-focused systematic review. *International journal of environmental research and public health*, *17*(7), p.2325.

Calderoni, L., Magnani, A. and Maio, D., 2019. IoT Manager: An open-source IoT framework for smart cities. *Journal of Systems Architecture*, *98*, pp.413-423.

Camero, A. and Alba, E., 2019. Smart City and information technology: A review. *cities*, *93*, pp.84-94.

Castelnovo, W., Misuraca, G. and Savoldelli, A., 2016. Smart cities governance: The need for a holistic approach to assessing urban participatory policy making. *Social Science Computer Review*, *34*(6), pp.724-739.

Caragliu, A. and Del Bo, C.F., 2019. Smart innovative cities: The impact of Smart City policies on urban innovation. *Technological Forecasting and Social Change*, *142*, pp.373-383.

Cerchecci, M., Luti, F., Mecocci, A., Parrino, S., Peruzzi, G. and Pozzebon, A., 2018. A low power IoT sensor node architecture for waste management within smart cities context. *Sensors*, *18*(4), p.1282.

Chatfield, A.T. and Reddick, C.G., 2016. Smart city implementation through shared vision of social innovation for environmental sustainability: A case study of Kitakyushu, Japan. *Social Science Computer Review*, *34*(6), pp.757-773.

Chatterjee, S., Kar, A.K. and Gupta, M.P., 2018. Success of IoT in smart cities of India: An empirical analysis. *Government Information Quarterly*, *35*(3), pp.349-361.

Chauhan, S., Agarwal, N. and Kar, A.K., 2016. Addressing big data challenges in smart cities: a systematic literature review. *info*.

Cocchia, A., 2014. Smart and digital city: A systematic literature review. *Smart city*, pp.13-43.

Colicchia, C. and Strozzi, F., 2012. Supply chain risk management: a new methodology for a systematic literature review. *Supply Chain Management: An International Journal*.

Corsini, F., Certomà, C., Dyer, M. and Frey, M., 2019. Participatory energy: Research, imaginaries and practices on people'contribute to energy systems in the smart city. *Technological Forecasting and Social Change*, *142*, pp.322-332.

Cowley, R. and Caprotti, F., 2019. Smart city as anti-planning in the UK. *Environment and Planning D: Society and Space*, *37*(3), pp.428-448.

De Falco, S., Angelidou, M. and Addie, J.P.D., 2019. From the “smart city” to the “smart metropolis”? Building resilience in the urban periphery. *European Urban and Regional Studies*, *26*(2), pp.205-223.

De Nooy, W., Mrvar, A. and Batagelj, V., 2018. *Exploratory social network analysis with Pajek: Revised and expanded edition for updated software* (Vol. 46). Cambridge university press.

Denyer, D. and Tranfield, D., 2009. Producing a systematic review.

Dutta, D., Pradhan, A., Acharya, O.P. and Mohapatra, S.K., 2019. IoT based pollution monitoring and health correlation: a case study on smart city. *International Journal of System Assurance Engineering and Management*, *10*(4), pp.731-738.

Estrada, E., Martinez Vargas, M.P., Gómez, J., Peña Pérez Negron, A., López, G.L. and Maciel, R., 2019. Smart cities big data algorithms for sensors location. *Applied Sciences*, *9*(19), p.4196.

Gabrys, J., 2014. Programming environments: Environmentality and citizen sensing in the smart city. *Environment and planning D: Society and space*, *32*(1), pp.30-48.

Gheisari, M., Wang, G. and Chen, S., 2020. An edge computing-enhanced internet of things framework for privacy-preserving in smart city. *Computers & Electrical Engineering*, *81*, p.106504.

Giffinger, R., Fertner, C., Kramar, H. and Meijers, E., 2007. City-ranking of European medium-sized cities. *Cent. Reg. Sci. Vienna UT*, pp.1-12.

Glasmeier, A. and Christopherson, S., 2015. Thinking about smart cities.

Goodspeed, R., 2015. Smart cities: moving beyond urban cybernetics to tackle wicked problems. *Cambridge Journal of Regions, Economy and Society*, *8*(1), pp.79-92.

Guo, Y.M., Huang, Z.L., Guo, J., Li, H., Guo, X.R. and Nkeli, M.J., 2019. Bibliometric analysis on smart cities research. *Sustainability*, *11*(13), p.3606.

Guo, M., Liu, Y., Yu, H., Hu, B. and Sang, Z., 2016. An overview of smart city in China. *China Communications*, *13*(5), pp.203-211.

Gupta, P., Chauhan, S. and Jaiswal, M.P., 2019. Classification of smart city research-a descriptive literature review and future research agenda. *Information Systems Frontiers*, *21*(3), pp.661-685.

Habibzadeh, H., Kaptan, C., Soyata, T., Kantarci, B. and Boukerche, A., 2019. Smart city system design: A comprehensive study of the application and data planes. *ACM Computing Surveys (CSUR)*, *52*(2), pp.1-38.

Hollands, R.G., 2008. Will the real smart city please stand up? Intelligent, progressive or entrepreneurial?. *City*, *12*(3), pp.303-320.

Hollands, R.G., 2015. Critical interventions into the corporate smart city. *Cambridge journal of regions, economy and society*, *8*(1), pp.61-77.

Hu, R., 2019. The state of smart cities in China: The case of Shenzhen. *Energies*, *12*(22), p.4375.

Huang, C.J. and Kuo, P.H., 2018. A deep cnn-lstm model for particulate matter (PM2. 5) forecasting in smart cities. *Sensors*, *18*(7), p.2220.

Huang-Lachmann, J.T., 2019. Systematic review of smart cities and climate change adaptation. *Sustainability Accounting, Management and Policy Journal*.

Ingwersen, P. and Serrano-López, A.E., 2018. Smart city research 1990–2016. *Scientometrics*, *117*(2), pp.1205-1236.

Israilidis, J., Odusanya, K. and Mazhar, M.U., 2021. Exploring knowledge management perspectives in smart city research: A review and future research agenda. *International Journal of Information Management*, *56*, p.101989.

Jin, J., Gubbi, J., Marusic, S. and Palaniswami, M., 2014. An information framework for creating a smart city through internet of things. *IEEE Internet of Things journal*, *1*(2), pp.112-121.

Kembro, J., Selviaridis, K. and Näslund, D., 2014. Theoretical perspectives on information sharing in supply chains: a systematic literature review and conceptual framework. *Supply chain management: An international journal*.

Kim, S., C. Colicchia, and D. Menachof. 2016. “Ethical Sourcing: An Analysis of the Literature and Implications for Future Research.” Journal of Business Ethics: 1–20. doi:10.1007/s10551-016-3266-8.

Kirimtat, A., Krejcar, O., Kertesz, A. and Tasgetiren, M.F., 2020. Future trends and current state of smart city concepts: A survey. *IEEE Access*, *8*, pp.86448-86467.

Kleinberg, J., 2003. Bursty and hierarchical structure in streams. *Data mining and knowledge discovery*, *7*(4), pp.373-397.

Kourtit, K., Nijkamp, P. and Arribas, D., 2012. Smart cities in perspective–a comparative European study by means of self-organizing maps. *Innovation: The European journal of social science research*, *25*(2), pp.229-246.

Kunzmann, K.R., 2020. Smart cities after covid-19: ten narratives. *disP-The Planning Review*, *56*(2), pp.20-31.

Lazaroiu, G.C. and Roscia, M., 2012. Definition methodology for the smart cities model. *Energy*, *47*(1), pp.326-332.

Lee, C.S., Goh, D.H.L., Osop, H., Sin, S.C.J. and Theng, Y.L., 2017. Public services or private gains: Motives behind participation on a mobile crowdsourcing application in a smart city. *Proceedings of the Association for Information Science and Technology*, *54*(1), pp.495-498.

Li, K., Yuen, C., Kanhere, S.S., Hu, K., Zhang, W., Jiang, F. and Liu, X., 2018. An experimental study for tracking crowd in smart cities. *IEEE Systems Journal*, *13*(3), pp.2966-2977.

Lim, Y., Edelenbos, J. and Gianoli, A., 2019. Identifying the results of smart city development: Findings from systematic literature review. *Cities*, *95*, p.102397.

Liu, Y., Zhang, W., Pan, S., Li, Y. and Chen, Y., 2020. Analyzing the robotic behavior in a smart city with deep enforcement and imitation learning using IoRT. *Computer Communications*, *150*, pp.346-356.

Lucio-Arias, D. and Leydesdorff, L., 2008. Main-path analysis and path-dependent transitions in HistCite™-based historiograms. *Journal of the American Society for Information Science and Technology*, *59*(12), pp.1948-1962.

Malik, A.W., Mahmood, I., Ahmed, N. and Anwar, Z., 2019. Big data in motion: A vehicle-assisted urban computing framework for smart cities. *IEEE Access*, *7*, pp.55951-55965.

Malik, K.R., Sam, Y., Hussain, M. and Abuarqoub, A., 2018. A methodology for real-time data sustainability in smart city: Towards inferencing and analytics for big-data. *Sustainable Cities and Society*, *39*, pp.548-556.

Manfreda, A., Ljubi, K. and Groznik, A., 2021. Autonomous vehicles in the smart city era: An empirical study of adoption factors important for millennials. *International Journal of Information Management*, *58*, p.102050.

Marrone, M. and Hammerle, M., 2018. Smart cities: A review and analysis of stakeholders’ literature. *Business & Information Systems Engineering*, *60*(3), pp.197-213.

Marsal-Llacuna, M.L., 2015, June. Measuring the Standardized Definition of “smart city”: A Proposal on Global Metrics to Set the Terms of Reference for Urban “smartness”. In *International Conference on Computational Science and Its Applications* (pp. 593-611). Springer, Cham.

Meijer, A. and Bolívar, M.P.R., 2016. Governing the smart city: a review of the literature on smart urban governance. *international review of administrative sciences*, *82*(2), pp.392-408.

Mohammadi, M., Al-Fuqaha, A., Guizani, M. and Oh, J.S., 2017. Semisupervised deep reinforcement learning in support of IoT and smart city services. *IEEE Internet of Things Journal*, *5*(2), pp.624-635.

Montori, F., Bedogni, L. and Bononi, L., 2017. A collaborative internet of things architecture for smart cities and environmental monitoring. *IEEE Internet of Things Journal*, *5*(2), pp.592-605.

Mora, L., Bolici, R. and Deakin, M., 2017. The first two decades of smart-city research: A bibliometric analysis. *Journal of Urban Technology*, *24*(1), pp.3-27.

Mora, L., Deakin, M. and Reid, A., 2019. Combining co-citation clustering and text-based analysis to reveal the main development paths of smart cities. *Technological Forecasting and Social Change*, *142*, pp.56-69.

Moustaka, V., Vakali, A. and Anthopoulos, L.G., 2018. A systematic review for smart city data analytics. *ACM Computing Surveys (CSUR)*, *51*(5), pp.1-41.

Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salvi, M. and Scapolo, F., Towards a green and digital future, EUR 31075 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-52451-9, doi:10.2760/977331, JRC129319.

Naseer, S., Liu, W. and Sarkar, N.I., 2019. Energy-efficient massive data dissemination through vehicle mobility in smart cities. *Sensors*, *19*(21), p.4735.

Nasiri, H., Nasehi, S. and Goudarzi, M., 2019. Evaluation of distributed stream processing frameworks for IoT applications in Smart Cities. *Journal of Big Data*, *6*(1), pp.1-24.

Nicolas, C., Kim, J. and Chi, S., 2020. Quantifying the dynamic effects of smart city development enablers using structural equation modeling. *Sustainable Cities and Society*, *53*, p.101916.

Nithya, S., Sundara Vadivel, P., Yuvaraj, D. and Sivaram, M., 2018. Intelligent based IoT smart city on traffic control system using raspberry Pi and robust waste management. *Journal of Advanced Research in Dynamical and Control Systems, Pages*, pp.765-770.

Papadopoulou, C.A. and Giaoutzi, M., 2019. Crowdsourcing and Living Labs in Support of Smart Cities' Development. In *Smart Cities and Smart Spaces: Concepts, Methodologies, Tools, and Applications* (pp. 652-670). IGI Global.

Paricio, A. and Lopez-Carmona, M.A., 2019. MuTraff: a smart-city multi-map traffic routing framework. *Sensors*, *19*(24), p.5342.

Park, S., Park, S.H., Park, L.W., Park, S., Lee, S., Lee, T., Lee, S.H., Jang, H., Kim, S.M., Chang, H. and Park, S., 2018. Design and implementation of a smart IoT based building and town disaster management system in smart city infrastructure. *Applied Sciences*, *8*(11), p.2239.

Pereira, G.V., Parycek, P., Falco, E. and Kleinhans, R., 2018. Smart governance in the context of smart cities: A literature review. *Information Polity*, *23*(2), pp.143-162.

Pinna, F., Masala, F. and Garau, C., 2017. Urban policies and mobility trends in Italian smart cities. *Sustainability*, *9*(4), p.494.

Pollack, J. and Adler, D., 2015. Emergent trends and passing fads in project management research: A scientometric analysis of changes in the field. *International Journal of Project Management*, *33*(1), pp.236-248.

Praharaj, S. and Han, H., 2019. Building a typology of the 100 smart cities in India. *Smart and Sustainable Built Environment*.

Prandi, C., Mirri, S., Ferretti, S. and Salomoni, P., 2017. On the need of trustworthy sensing and crowdsourcing for urban accessibility in smart city. *ACM Transactions on Internet Technology (TOIT)*, *18*(1), pp.1-21.

Purnomo, F. and Prabowo, H., 2016. Smart city indicators: A systematic literature review. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, *8*(3), pp.161-164.

Quijano-Sánchez, L., Cantador, I., Cortés-Cediel, M.E. and Gil, O., 2020. Recommender systems for smart cities. *Information systems*, *92*, p.101545.

Ruhlandt, R.W.S., 2018. The governance of smart cities: A systematic literature review. *Cities*, *81*, pp.1-23.

Schuurman, D., Baccarne, B., De Marez, L. and Mechant, P., 2012. Smart ideas for smart cities: Investigating crowdsourcing for generating and selecting ideas for ICT innovation in a city context. *Journal of theoretical and applied electronic commerce research*, *7*(3), pp.49-62.

Semanjski, I. and Gautama, S., 2015. Smart city mobility application—gradient boosting trees for mobility prediction and analysis based on crowdsourced data. *Sensors*, *15*(7), pp.15974-15987.

Shelton, T. and Lodato, T., 2019. Actually existing smart citizens: Expertise and (non) participation in the making of the smart city. *City*, *23*(1), pp.35-52.

Simonofski, A., Vallé, T., Serral, E. and Wautelet, Y., 2021. Investigating context factors in citizen participation strategies: A comparative analysis of Swedish and Belgian smart cities. *International Journal of Information Management*, *56*, p.102011.

Smigiel, C., 2019. Urban political strategies in times of crisis: A multiscalar perspective on smart cities in Italy. *European Urban and Regional Studies*, *26*(4), pp.336-348.

Söderström, O., Paasche, T. and Klauser, F., 2020. Smart cities as corporate storytelling. In *The Routledge Companion to Smart Cities* (pp. 283-300). Routledge.

Soomro, K., Bhutta, M.N.M., Khan, Z. and Tahir, M.A., 2019. Smart city big data analytics: An advanced review. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, *9*(5), p.e1319.

Soomro, S., Miraz, M.H., Prasanth, A. and Abdullah, M., 2018. Artificial intelligence enabled IoT: traffic congestion reduction in smart cities.

Souza, J.T.D., Francisco, A.C.D., Piekarski, C.M. and Prado, G.F.D., 2019. Data mining and machine learning to promote smart cities: A systematic review from 2000 to 2018. *Sustainability*, *11*(4), p.1077.

Steenbruggen, J., Tranos, E. and Nijkamp, P., 2015. Data from mobile phone operators: A tool for smarter cities?. *Telecommunications Policy*, *39*(3-4), pp.335-346.

Strozzi, F., Colicchia, C., Creazza, A. and Noè, C., 2017. Literature review on the 'Smart Factory'concept using bibliometric tools. *International Journal of Production Research*, *55*(22), pp.6572-6591.

Sun, X. and Ansari, N., 2017. Dynamic resource caching in the IoT application layer for smart cities. *IEEE Internet of Things Journal*, *5*(2), pp.606-613.

Sundhari, R.M. and Jaikumar, K., 2020. IoT assisted Hierarchical Computation Strategic Making (HCSM) and Dynamic Stochastic Optimization Technique (DSOT) for energy optimization in wireless sensor networks for smart city monitoring. *Computer Communications*, *150*, pp.226-234.

Talari, S., Shafie-Khah, M., Siano, P., Loia, V., Tommasetti, A. and Catalão, J.P., 2017. A review of smart cities based on the internet of things concept. *Energies*, *10*(4), p.421.

Tang, B., Chen, Z., Hefferman, G., Pei, S., Wei, T., He, H. and Yang, Q., 2017. Incorporating intelligence in fog computing for big data analysis in smart cities. *IEEE Transactions on Industrial informatics*, *13*(5), pp.2140-2150.

Teng, H., Liu, Y., Liu, A., Xiong, N.N., Cai, Z., Wang, T. and Liu, X., 2019. A novel code data dissemination scheme for Internet of Things through mobile vehicle of smart cities. *Future Generation Computer Systems*, *94*, pp.351-367.

Toli, A.M. and Murtagh, N., 2020. The concept of sustainability in smart city definitions. *Frontiers in Built Environment*, *6*, p.77.

Toma, C., Alexandru, A., Popa, M. and Zamfiroiu, A., 2019. IoT solution for smart cities' pollution monitoring and the security challenges. *Sensors*, *19*(15), p.3401.

Townsend, A.M., 2013. *Smart cities: Big data, civic hackers, and the quest for a new utopia*. WW Norton & Company.

Trindade, E.P., Hinnig, M.P.F., Moreira da Costa, E., Marques, J.S., Bastos, R.C. and Yigitcanlar, T., 2017. Sustainable development of smart cities: A systematic review of the literature. *Journal of Open Innovation: Technology, Market, and Complexity*, *3*(3), p.11.

UN, 2018. World urbanization prospects: the 2018 revision. accessed on 6. 6. 2019. https://population.un.org/wup//Publications/Files/WUP2018-KeyFacts.pdf.

Van Eck, N.J. and Waltman, L., 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. *scientometrics*, *84*(2), pp.523-538.

Vanolo, A., 2014. Smartmentality: The smart city as disciplinary strategy. *Urban studies*, *51*(5), pp.883-898.

Vanolo, A., 2016. Is there anybody out there? The place and role of citizens in tomorrow's smart cities. *Futures*, *82*, pp.26-36.

Vinceti, M., Filippini, T., Rothman, K.J., Ferrari, F., Goffi, A., Maffeis, G. and Orsini, N., 2020. Lockdown timing and efficacy in controlling COVID-19 using mobile phone tracking. *EClinicalMedicine*, *25*, p.100457.

Walters, D., 2011. Smart cities, smart places, smart democracy: Form-based codes, electronic governance and the role of place in making smart cities. *Intelligent Buildings International*, *3*(3), pp.198-218.

Winkowska, J., Szpilko, D. and Pejić, S., 2019. Smart city concept in the light of the literature review. *Engineering Management in Production and Services*, *11*(2).

Yigitcanlar, T. and Kamruzzaman, M., 2018b. Does smart city policy lead to sustainability of cities?. *Land use policy*, *73*, pp.49-58.

Yigitcanlar, T., Kamruzzaman, M., Buys, L., Ioppolo, G., Sabatini-Marques, J., da Costa, E.M. and Yun, J.J., 2018a. Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework. *Cities*, *81*, pp.145-160.

Yigitcanlar, T. and Kamruzzaman, M., 2019d. Smart cities and mobility: does the smartness of Australian cities lead to sustainable commuting patterns?. *Journal of Urban Technology*, *26*(2), pp.21-46.

Yigitcanlar, T., Foth, M. and Kamruzzaman, M., 2019c. Towards post-anthropocentric cities: Reconceptualizing smart cities to evade urban ecocide. *Journal of Urban Technology*, *26*(2), pp.147-152.

Yigitcanlar, T., Han, H., Kamruzzaman, M., Ioppolo, G. and Sabatini-Marques, J., 2019b. The making of smart cities: Are Songdo, Masdar, Amsterdam, San Francisco and Brisbane the best we could build?. *Land Use Policy*, *88*, p.104187.

Yigitcanlar, T., Han, H. and Kamruzzaman, M., 2019a. Approaches, advances, and applications in the sustainable development of smart cities: A commentary from the guest editors.

Yoo, Y., Kim, K. and Han, J., 2016. Comparative analysis of smart city projects∗-implications for U-city. *International Journal of Applied Business and Economic Research*, *14*(5), pp.2913-2929.

You, L., Tunçer, B., Zhu, R., Xing, H. and Yuen, C., 2019. A synergetic orchestration of objects, data, and services to enable smart cities. *IEEE Internet of Things Journal*, *6*(6), pp.10496-10507.

Zawieska, J. and Pieriegud, J., 2018. Smart city as a tool for sustainable mobility and transport decarbonisation. *Transport Policy*, *63*, pp.39-50.

Zhang, B., Liu, C.H., Tang, J., Xu, Z., Ma, J. and Wang, W., 2017. Learning-based energy-efficient data collection by unmanned vehicles in smart cities. *IEEE Transactions on Industrial Informatics*, *14*(4), pp.1666-1676.

Zheng, C., Yuan, J., Zhu, L., Zhang, Y. and Shao, Q., 2020. From digital to sustainable: A scientometric review of smart city literature between 1990 and 2019. *Journal of Cleaner Production*, *258*, p.120689.

Zvolska, L., Lehner, M., Voytenko Palgan, Y., Mont, O. and Plepys, A., 2019. Urban sharing in smart cities: the cases of Berlin and London. *Local Environment*, *24*(7), pp.628-645.

List of abbreviations and definitions

AI	Artificial Intelligence
CAN	Citation Network Analysis
C-IoT	Collaborative Internet of Things
CSI-RS	channel state information reference signal
CSI-RS	channel state information reference signal
DL	Deep Learning
EC	European Commission
IoE	Internet of Everything
IoRT	Internet of Robotic Things
IoT	Internet of Things
JRC	Joint Research Centre
MIMO	multi-input multi-output
ML	Machine Learning
PAAS	Platform as A Service
SC	Smart City
SCs	Smart Cities
SLNA	Systematic Literature Network Analysis
SLNA-P	Systematic Literature Network Analysis-Patents
SLR	Systematic Literature Review
VoS	Visualisation of Similarities
CIMO	Context Intervention Mechanism and Autcome
ICT	Information and Communication Technologies
KPI	Key Performance Indicators

List of figures

List of tables

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

Publications Office
of the European Union