Smart City Development Paths: Insights from the First Two Decades of Research

Luca Mora[1], Mark Deakin[2], Alasdair Reid[3]

Abstract

More than 20 years have now passed since the concept of smart city first appeared in a scholarly publication, marking the beginning of a new era in urban innovation. Since then, the literature discussing this new concept and the ICT-oriented urban-innovation approach it stands for has been growing steadily, along with the number of initiatives that cities all over the world have launched to pursue their ambition of becoming smart. However, current research still falls short of providing a clear understanding of smart cities and the scientific knowledge policy makers and practitioners both need to deal with their progressive development. In response to this shortfall, this paper offers a bibliometric study of the first two decades of smart-city research, whereby citation link-based clustering and text-based analysis are combined to: (1) build and visualize the network of scholarly publications shaping the intellectual structure of the smart city research field; (2) identify the clusters of thematically related publications; and (3) reveal the emerging development paths of smart cities that these clusters support and the strategic principles they embody. This study uncovers five main development paths: the Experimental Path; the Ubiquitous Path; the Corporate Path; the European Path; and the Holistic Path. Overall, this analysis offers a comprehensive and systematic view of how a smart city can be understood theoretically and as a scientific object of knowledge able to inform policy-making processes.

Keywords: smart cities; urban innovation; bibliometric analysis; co-citation analysis; content analysis; development paths

1. Introduction: Smart city, One Term, Different Interpretations

As Meijer and Bolivar (2016) note, there is still little agreement over what makes a city smart. Evidence of this trend is provided by Hollands (2008), Paskaleva (2011), Nam and Pardo (2011a; 2011b), Alkandari et al. (2012), Chourabi et al. (2012), Albino et al. (2015) and, more recently, by Komninos and Mora (2018) and Mora et al. (2017: 20), whose bibliometric analyses reveal that the disagreement in the ways of conceptualizing and defining the smart city results from the *"lack of intellectual exchange"* between smart-city researchers and their *"tendency [...] to be subjective and follow personal trajectories in isolation from one another"*.

This paper suggests all these subjective, personal and isolated interpretations fall short of providing both a clear understanding of smart cities and the scientific knowledge policy makers and practitioners need to deal with their progressive development. Indeed, we suggest this division is now so entrenched within the scientific community that it has generated different development paths for smart cities. This critical insight is drawn from research by Lazaroiu and Roscia (2012), Zygiaris (2013), Komninos (2014), Deakin (2013), Hollands (2015), Bolici and Mora (2015) and Mora and Bolici (2016; 2017) and serves to corroborate their findings on the state of the art.

In the interests of bridging this division within the scientific community, this paper reports on the findings of a bibliometric study covering the first two decades of research on smart cities. In this study, citation link-based clustering and text-based analysis are combined to: (1) build and visualize the network of scholarly publications shaping the intellectual structure of the smart-city research field; (2) identify the clusters of thematically related publications that shape the intellectual structure of the smart-city research field; and (3) reveal the emerging development paths of smart cities that these clusters support, along with the strategic principles they embody. This analysis offers a comprehensive and systematic view of how a smart city is understood by the scientific community and helps to bridge the structural divisions affecting smart-city research by supporting *"the construction of [that] collaborative environment which is necessary to generate a possible agreement concerning the way of thinking*

---

[1] Edinburgh Napier University, School of Engineering and Built Environment, Edinburgh, UK, L.Mora@napier.ac.uk

[2] Edinburgh Napier University, School of Engineering and Built Environment, Edinburgh, UK

[3] Edinburgh Napier University, School of Engineering and Built Environment, Edinburgh, UK

about, conceptualizing and defining the smart city" (Mora et al. 2017: 21).

2. Research Methodology

In this bibliometric study, the hybrid techniques proposed by Braam et al. (1991a; 1991b) and Glanzel and Czerwon (1996) are applied to analyze the intellectual structure of the smart-city research field and identify the main development paths. This structure is first outlined and graphically visualized and then split into sub-groups of publications by conducting a document co-citation analysis. The result is a co-citation network composed of 2,273 publications divided into 18 thematic clusters. After tracing the network of relationships between these documents, a description of the content relating to the most representative clusters is provided based on the identification of their core documents[4] and the construction of word profiles.

The study begins with a keyword search that aims to develop a representative dataset of literature on smart cities. The literature search covers the period from the beginning of 1992 to the end of 2012 and is implemented by using multiple scholarly databases. This search makes it possible to identify all the English-language literature containing the term smart city in the title, abstract, keyword list or within the body of the text. The following search query is used: "smart city" OR "smart cities" (Baseline 1992)[5]. It is important to note that all types of documents are considered in this study, including grey literature[6] (Schopfel and Farace 2010).

The documents found by using this search criteria are then included in a single dataset and checked to identify and correct any errors in the titles, names of authors and publication dates. Duplicate documents that are found in more than one database are eliminated. Finally, the title, abstract, keyword list and body of the text of each remaining publication are manually examined to verify the effective presence of the keyword. Documents for which this search is negative are eliminated.

After completing the search phase, the publications remaining in the dataset are 1,067, and all of them are used to collect the raw data needed to conduct the bibliometric study. For this reason, they can be considered as source documents (Small and Crane 1979; Schneider et al. 2009; Shiau and Dwivedi 2013; Ingwersen et al. 2014). Data for the co-citation analysis is collected manually by extracting the list of references from each source document. Altogether, 22,137 citations are extracted and used to build a frequency table showing each cited publication, along with the number of citations it has received. The total number of cited references is 17,574.

By considering only the 2,273 cited references with at least two citations, a co-citation network is then outlined, whereby each cited reference is represented as a node. Only 124 source documents are included in the network, where the nodes that are co-cited are connected with an edge. The total number of edges is 45,534 and their weight is measured considering the CoCit-Score, which is calculated according to the formula proposed by Allmayer and Winkler (2013) and Gmur (2003). Subsequently, nodes and edges are entered into the open source software Gephi (Version 0.8.2-beta) and the co-citation network is graphically visualized. The result is an undirected and weighted network which is subsequently split into sub-networks using Gephi's modularity-class algorithm. The sub-networks represent the thematic clusters, i.e., groups of densely connected publications that are used to identify the main development paths within the smart-city research field.

3. Results of Data Processing

The results obtained through data processing are summarized in Table 1[7] and displayed in Fig. 1, which graphically represents the co-citation network. Within the network, each publication is represented as

---

[4] In this study, core documents of a thematic cluster are considered as those publications with the highest number of connections with other publications in the same cluster.

[5] The following databases are used to conduct the keyword search: Google Scholar; ISI Web of Science; IEEE Xplore; Scopus; SpringerLink; Engineering Village; ScienceDirect; and Taylor and Francis Online. Considering the specific interest of this study for smart cities, a decision was made to set the keyword search so that only the scholarly publications containing the singular of plural form of the term 'smart city' are identified and not the literature using other terms that are considered as equivalent despite having different meanings (Hollands 2008). These terms include sustainable cities, green cities, digital cities, intelligent cities, smarter cities, information cities, resilient cities, eco cities, low-carbon cities and liveable cities. This choice is based on research by de Jong (2015), which reveals these categories of cities are characterized by conceptual and practical differences and cannot be used interchangeably with the term "smart city".

[6] Grey literature can be considered as *"all the scholarly work that is published without a formal peer-review (or equivalent) process outside the traditional journal and book channels"* (Schopfel 2010).

[7] All the tables (Table 1, Table 2 and Table 3) can be found in Appendix A.

a node in which the size of the circle is proportional to its degree of centrality. This attribute is calculated by adding up the number of times the publication is co-cited. The greater the quantity of co-citations associated with a node, the greater its number of links within the network and, consequently, its centrality in the whole system. The same approach is extended to clusters by summing up the values obtained for each of their publications.
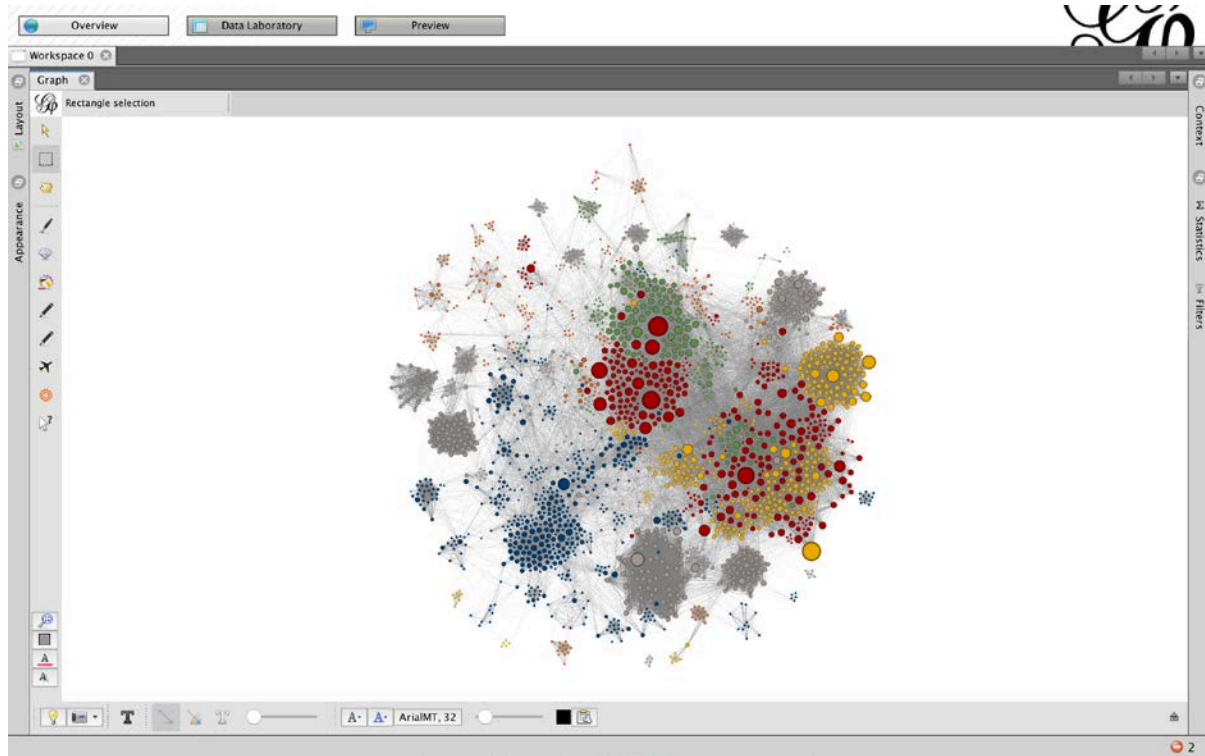

Fig. 1: Co-citation network: the intellectual structure of the smart-city research field for the period 1992-2012. Screenshot from Gephi. Within the network, each publication is represented as a node in which the size of the circle is proportional to its degree of centrality. Blue: mc.02; Yellow: mc.05; Green: mc.08; Orange: mc.14; Red: mc.17; Grey: others.

The network is composed of 18 thematic clusters in which the distribution of source documents varies considerably. The clusters are labelled from mc.01 to mc.18, and how they breakdown is shown in Table 1. The sub-networks mc.02, mc.05, mc.08, mc.14 and mc.17 can be considered as the main thematic clusters. In addition to containing the largest number of publications, they also include most of the source documents. Given their dominant role in the co-citation network, these clusters are used to provide insight into the intellectual structure of the smart-city research field. To achieve this aim, their content is analyzed by combining the use of core documents (Glanzel and Czerwon 1996; Glanzel and Thijs 2011; Meyer et al. 2013) and word profiles (Braam et al. 1991a; 1991b).

Five core documents for each cluster are selected by considering the in-degree measurement of the publications falling into them. This attribute represents the sum of internal relationships that a document has with other publications of the same cluster and can be used for measuring the degree of centrality in that cluster (Gmur 2003). Because of their high connectivity, these documents provide most of the information about the content of the clusters. A list of the core documents is provided in Table 2.

In addition, for each of the five clusters, a word profile with ten keywords is built by combining the full-texts of its source documents. More specifically, a file containing the textual data of each source document is created. These text files are then analyzed using the software WordStat (Version 6.0) to extract and combine the words and phrases contained in the source documents and estimate their frequency and occurrence. The keywords included in the word profiles are the phrases with the highest frequency that are found in at least 30% of the source documents belonging to the cluster (see Table 3).

4. The Smart-City Research Field: Main Development Paths

After completing the bibliometric analysis, word profiles and core documents are used to outline an in-

depth description of the main thematic clusters and to shed light on the main development paths emerging from the intellectual structure of the smart city research field.

4.1. Cluster mc.02 - Experimental Path: Smart Cities as Testbeds for IoT Solutions

Interest in the technological component is dominant in the smart-city research field and represents one of the main driving forces behind its progressive growth. This becomes evident by observing the clusters' word profiles, in which Information Technology (IT) and Information and Communication Technology (ICT) are always two of the keywords with the highest frequency. Additional evidence is also provided by the content analysis of the sub-network mc.02, which is the largest thematic cluster of the co-citation network. 25.4% of the total 2,273 publications are part of this cluster, where research focuses attention on ICT devices and infrastructures that have enabled ubiquitous computing and the Internet of Things (IoT), and stresses the potential contribution that they can offer in supporting cities' sustainable development. Some of the technological components discussed in the core documents are indeed included in the cluster's word profile: sensor networks; RFID tags; mobile devices; mobile phones; and wireless sensors.

Ubiquitous computing is one of the key technical visions underlying the IoT (ITU 2005) and originates from the work carried out by a group of researchers at Xerox PARC in Palo Alto, California. This group was led by Weiser (1991), who was the first to discuss this concept in a scholarly publication. As explained by Weiser et al. (1999), ubiquitous computing is based on the idea of spreading computers throughout the physical environment, moving away from the one-person-one-computer paradigm. According to his vision, formulated in the early 1990s, computers will be diffused in the real world and interconnected by ubiquitous networks. In addition, they will be able to control a countless range of functions in the physical space and work without human intervention, as autonomous and invisible agents (Weiser 1993). This vision becomes a reality with the advent of wireless technologies that activate a large number of networks composed of physical objects containing embedded technology to populate the Internet and communicate, sense and interact with both their internal states and the external environment in a completely autonomous way (Mitchell 2003).

This emerging wave of Internet-connected things leads to the appearance of the IoT, a new concept which is rapidly growing within the scenario of the potential benefits of ICTs in the sustainable development of urban environments. Despite difficulties in understanding what this term really means, due to the numerous interpretations provided by the scientific community, *"the basic idea of this concept is the pervasive presence around us of a variety of things or objects, such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc., which […] are able to interact with each other and cooperate with their neighbors to reach common goals"* (Atzori et al. 2010: 2787). All these things can be called smart objects, that are *"small computers with a sensor or actuator and a communication device, embedded in objects such as thermometers, car engines, light switches and industry machinery [which] enable a wide range of applications"* (Sundmaeker et al. 2010: 15).

The IoT can be considered as an integral part of the Future Internet (Atzori et al. 2010; ITU 2005; Tselentis et al. 2009) and an extension of the existing Internet, which generates new digital services and applications. The fields of application are many and include agriculture, home automation, building automation, factory monitoring, health-management systems, education, smart grids, transportation and, in a broader vision, smart cities (Holler et al. 2014; Sundmaeker et al. 2010). As reported by Miorandi et al. (2012: 1510), indeed, *"IoT technologies can find a number of diverse applications in smart cities' scenarios"*. Based on this assumption, the thematic cluster mc.02 interprets smart cities as cities and urban territories that become testbeds for experimenting IoT technologies and analyzing their functioning, relevance and potential impact in real-life environments, as in the case of Santander, that is described in the cluster's publications (Sanchez et al. 2011; 2013).

Located on the north coast of Spain, this small city has become an urban laboratory for the European research project SmartSantander. During the project, Santander and its surroundings have been equipped with more than 12,000 IoT devices (Sanchez et al. 2011) and transformed into *"a European experimental test facility for the research and experimentation of architectures, key enabling technologies, services and applications for the IoT in the context of a smart city"* (Sanchez et al. 2013: 1). According to the consortium leading the project, this facility should be *"instrumental in fostering key enabling technologies for IoT and providing the research community with a […] platform for large scale IoT experimentation and evaluation under realistic operational conditions"* (Sanchez et al. 2013: 1).

4.2. Cluster mc.05 - Ubiquitous Path: the Korean Experience of Ubiquitous Cities

Within the cluster mc.05, smart city and ubiquitous city are considered as two equivalent terms (Lee et al. 2008). Both are described as a technical evolution of the knowledge-city concept, which is discussed in a number of source documents of this thematic cluster (Dvir and Pasher 2004; Yigitcanlar et al.

2008a; 2008d) and in the core documents published by Yigitcanlar et al. (2008b; 2008c). Knowledge city is a term resulting from research on the knowledge economy and is used to identify cities where knowledge production is one of the main key drivers of their development strategy (Yigitcanlar et al. 2008d). As suggested by Yigitcanlar et al. (2008b), in the knowledge economy, urban development is mainly driven by global market forces and the role of knowledge in wealth creation has become a critical issue for cities. Therefore, it is necessary to define new approaches able to exploit the opportunities this abstract production offers for supporting sustainable growth and innovation in urban environments. This idea is supported in research carried out in the early years of 2000s by Landry (2000) and Florida (2002; 2005), both engaged in discussing and demonstrating the growing importance of knowledge and information in urban development processes, especially in terms of economic development and competitiveness.

Knowledge cities *"firmly encourage and nurture locally focused innovation, science and creativity within the context of an expanding knowledge economy and society"* (Yigitcanlar et al 2008a: 63). This implies the progressive implementation of a growth-oriented path based on more viable and sustainable models of urban development. According to Yigitcanlar et al. (2008a) and Lee et al. (2008), the possibility to achieve this aim by leveraging ICTs has marked the shift from the knowledge city to the ubiquitous city (or u-city). This term comes from the concept of ubiquitous computing proposed by Weiser (1991) and is used to identify urban areas equipped with ubiquitous technologies that offer citizens and visitors the possibility to use digital services anywhere and anytime. Such services provide them with access to data and information, mainly collected in real time, which describe the functioning of the city (Shin 2007; 2010; Shin and Kim 2010; Lee et al. 2008). Ubiquitous cities are therefore places where all information systems are linked together and everyone is connected to them (Shin and Kim 2010).

Most of the attention received by this concept comes from the Republic of Korea, where a national program on ubiquitous cities was launched by the central government in 2007. The aim was building the world's first u-society based on the world's best u-infrastructure (Republic of Korea 2007b). Only a few practical experiences linked to the ubiquitous city concept and developed outside the Korean territory can be found in scholarly literature. For example, Anthopoulos and Fitsilis (2010a; 2010b) describe the activity developed by the city of Trikala, Greece, while research by Gil-Castineira et al. (2011) and Shin and Lee (2011) report on a number of projects that are implemented in Oulu, San Francisco, Philadelphia, Tokyo, Singapore, Hong Kong, Taiwan and Malaysia.

The initiative of the South Korean government has driven many municipal administrations to integrate ubiquitous technologies in their urban environments. In 2007, the construction of u-cities extended to 22 cities (Republic of Korea 2007a), and, only three years later, they become 36, with a total number of 53 ubiquitous city initiatives in progress (Tekes 2011). Among the many projects developed under the ubiquitous city brand, Busan Green u-City, Songdo International Business District and Incheon Eco-City seem to be the most discussed in the cluster's literature, in which they are described overlapping the terms smart city and u-city[8] (GSMA 2012; Strickland 2011; Juan et al. 2011).

The Korean experience of ubiquitous cities has been analyzed in-depth and criticized by Shin (2007; 2009; 2010). His research sheds light on the limits and weaknesses of this national program, which is based on a top-down approach and *"is largely biased toward industrial and economic development, reflecting business providers' interests and leaving out users' […] benefits"* (Shin 2007: 636). According to Shin (2009; 2010), the many actors involved in the development of u-cities only appear to be interested in technical and market perspectives, competitiveness, financial aspects and economic impacts, rather than city users and their needs. As a consequence, *"South Korean u-cities, in general, fall short of the ontologically bounded […] information society [and] tend to be designed primarily to serve the demands of major corporate suppliers and industry at the expense of public interests. The primary driving force to develop the u-cities has been the arrangement or outlay of technological equipment to increase technical capability"* (Shin 2009: 516).

4.3. Cluster mc.08 - Corporate Path: IBM and the Corporate Smart-City Model

The technology-led vision of smart cities proposed in the cluster mc.05 is the engine that fuels ICT multinational companies and their involvement in the smart city market, which is expected to exceed hundreds of billion dollars by 2020 (Zanella et al. 2014; Buscher and Doody 2013). Driven by the will to acquire a strong position in this new and promising market, companies such as Cisco Systems (Amato et al. 2012a; 2012b; 2012c), Hitachi (Kohno et al. 2011; Kurebayashi et al. 2011; Yoshikawa et al. 2011), Fujitsu (Tamai 2014) and IBM (Brech et al. 2011; Cosgrove et al. 2011; Kehoe 2011; Katz and Ruano 2011; Paul et al. 2011; Ruano et al. 2011; Schaefer et al. 2011; Chen-Ritzo et al. 2009; Harrison et al. 2010; 2011) have started working in the domain of urban technology and feeding the smart-city debate.

---

[8] This tendency can also be found in more recent studies by Yigitcanlar and Lee (2014), Clarke (2013) and Shwayri (2013).

This trend has led to the growth of the corporate smart-city model discussed and criticized in recent research by Hollands (2008; 2015; 2016), Townsend (2013), Soderstrom et al. (2014) and McNeill (2016). According to Hollands (2015), in the corporate model, the smart city represents a technology-led urban utopia. Cities are conceived as systems of systems affected by inefficiencies that can be eliminated by using a massive dose of technological solutions provided by ICT companies (Soderstrom et al. 2014). The presence of these technologies automatically enable the transformation of ordinary urban environments in smart cities.

The corporate smart-city model has resulted in a new urbanism, whereby IT solution providers try to persuade municipalities to support urban development by adopting their smart technologies. IBM is one of the main supporter of this model and its relevant role and influence in the smart-city debate are demonstrated by the content analysis of the thematic cluster mc.08. This sub-network is almost totally linked to the vision proposed by the US multinational company. The cluster's most-cited source documents are produced by its researchers and their degree of centrality is significantly high (Moss Kanter and Litow 2009; Dirks et al. 2009; 2010; Dirks and Keeling 2009; Harrison et al. 2010), indeed, four out of five core documents are publications from IBM. What is more, the word profile contains the term smarter city, which is a trademark officially registered by this company and used for its smart-city campaign, under the motto: Building a Smarter Planet (Palmisano 2008).

The IBM's Smarter Planet initiative is a commercial venture launched at the end of 2008 and has positioned IBM at the forefront of smart city construction (Palmisano 2008; IBM Corporation 2017). Many cities all over the world have embraced its view of a smart city, which is based on the following assumption: to build a smarter planet, its cities need to be instrumented, interconnected and intelligent (Harrison et al. 2010). As explained by Dirks et al. (2009: 1): *"Instrumentation enables cities to gather more high-quality data in a timely fashion than ever before. For example, utility meters and sensors that monitor the capacity of the power generation network can be used to continually gather data on supply and demand of electricity […]. Interconnection creates links among data, systems and people […], opening up new ways to gather and share information. Intelligence - in the form of new kinds of computing models and new algorithms - enables cities to generate predictive insights for informed decision making and action. Combined with advanced analytics and ever-increasing storage and computing power, these new models can turn the mountains of data generated into intelligence to create insight as a basis for action"*. According to IBM, this ICT-based transformation can automatically make any city smarter and, consequently, more efficient, democratic, livable, attractive, environment-friendly, and economically prosperous (Dirks and Keeling 2009).

One of the flagship project falling within the Smarter Planet initiative has been developed in Rio de Janeiro. With an investment of 14 million dollars, the municipal administration has worked with IBM to build an emergency response system. Their collaboration has resulted in the Rio Operations Center, which opened at the end of 2010. The Center is based on a digital platform applying the analytical models developed by IBM, which are asked to: (1) provide a holistic view of how the city is functioning; and (2) predict possible emergency situations, especially flood-related incidents, because every summer Rio de Janeiro faces the consequences of intense rainfall, including landslides and flooding. The data used for predicting emergency includes: real-time images captured by a surveillance system with 900 cameras located around the city; weather sensors; historical data series; and the messages that are sent by the city's users via phone, Internet and radio (IBM Corporation 2011; Naphade et al. 2011; Kitchin 2014). The project has been criticized because: the top-down surveillance system generates negative social implications in terms of privacy; the civil society has not been engaged and actively involved in the implementation process; and IBM's technological solutions and computer algorithms are put in charge of city management, leaving very limited space for the human component (Singer 2012; Townsend 2013).

4.4. Cluster mc.14 - European Path: Smart City for a Low-Carbon Economy

According to data provided by the American Association for the Advancement of Science (2001) and the United Nations Human Settlements Programme (2011), urban areas: host more than 50% of the world's population; consume about 70% of the global energy; and release more than 70% of the carbon dioxide, which is damaging the Earth's atmosphere. These numbers provide a clear picture of the role played by the urbanized world in intensifying the environmental crisis and accelerating climate change. Fighting against this situation has become one of the most relevant priority for local and national governments, which are offering their contribution by implementing sustainable energy policies, initiatives and projects.

ICTs have proven to be a decisive means in helping governments to face up to this critical situation and enable the progressive growth of a low-carbon future. The core documents of the thematic cluster mc.14 explore this possibility, in particular the report *"SMART 2020"* published by The Climate Group, an international non-profit organization that supports leaders in government, business world and society to address climate risks and accelerate the transition to a low-carbon economy. This report

demonstrates the ICT industry's technological solutions can drastically unlock emissions reductions. More specifically, according to the authors, *"the biggest role ICTs could play is in helping to improve energy efficiency in power transmission and distribution (T&D), in buildings and factories that demand power, and in the use of transportation to deliver goods"* (The Climate Group 2008: 9). By acting on these five sectors, ICTs could *"deliver emissions saving of 15% […] of global […] emissions in 2020"* (The Climate Group 2008: 7).

This study and the other core documents make it clear that unlocking the potential of ICTs is the critical challenge which faces climate change globally. In addition, they identify the sector of smart grids as one of the most promising application domain. Smart grids are described as the electricity networks of the future because they improve the efficiency of current power transmission and distribution networks while responding to the new challenges and opportunities arising from the energy market (European Commission 2006; The Climate Group 2008; Karnouskos and Nass de Holanda 2009).

The importance and urgency of modernizing current electric power infrastructures by transforming them into smart grids is widely recognized. The Indian government has been developing policies to overcome barriers that limit the implementation of smart grid initiatives since 2001 (The Climate Group 2008). In 2005, the European Commission has set up the SmartGrids Technology Platform, in which all the relevant European stakeholders working in the energy sector have been included. Together, they designed a joint vision for the European energy network of 2020 and beyond that is based on activating smart-grid solutions across Europe (European Commission 2006). The same aim is pursued by the US government, where specific interoperability standards and protocols for smart-grid devices and systems have been established to accelerate their diffusion in the US territory (US Department of Commerce - NIST 2010).

Mobilizing ICTs to facilitate the transition to an energy-efficient and low-carbon economy is a key ambition of the European Union. This is demonstrated by the contents of the Strategic Energy Technology Plan (SET-Plan), that was published in 2009: a policy instrument that describes the strategy of the European Union for accelerating innovation in cutting-edge low-carbon technologies and their diffusion across Europe (European Commission 2009a).

This is the context in which the European interpretation of the smart-city concept supported in the cluster mc.14 has grown. As reported in the SET-plan, according to the European Commission, smart cities are those that will *"create the conditions to trigger the mass market take-up of energy efficiency technologies [by transforming] their buildings, energy networks and transport systems into those of the future, demonstrating transition concepts and strategies to a low carbon economy […]. These cities will be the nuclei from which smart networks, a new generation of buildings and low carbon transport solutions will develop into European wide realities that will transform [the] energy system"* (European Commission 2009a: 7).

4.5. Cluster mc.17 - Holistic Path: Digital, Intelligent, Smart

The thematic cluster mc.17 is the second sub-network of the system in terms of size and has the highest degree of centrality. Here the debate on smart cities is linked to the scientific foundations of *"urban ICT studies"* (Graham 2004a: 3), a sub-discipline of urban studies in which research aims at better understanding the relationship between ICT and the urban environment. This knowledge area starts growing between the end of 1990s and the early 2000s, and some of the first publications that have provided a significant contribution in laying down its intellectual structure are part of this cluster (Castells 1996; Graham and Marvin 1996; 2001; Mitchell 1995; 1999; 2003), including the book *"The Cybercities Reader"* (Graham 2004b), which is one of the core documents.

These publications and their authors started filling *"the gap left by the long neglect of telecommunications in urban studies and policy-making [by exploring] the complex and poorly understood set of relationships between telecommunications and the development, planning and management of contemporary cities"* (Graham and Marvin 1996: XII). In the meantime, cities all over the world started experimenting with the use of digital technologies for supporting urban innovation and development by implementing projects and initiatives which have been labeled by using three different terms: digital city; intelligent city; and smart city. These terms clearly emerges in both the cluster's word profile and the core documents by Ishida and Isbister (2000), Komninos (2002; 2006) and Caragliu et al. (2009).

The term digital city dates back to the end of the 20th century and is used as a label for a number of projects launched by European, North American and Asian cities (Ishida and Isbister 2000). These projects have resulted in the construction of websites that were used for providing access to cities' digital services. The aim was supporting social and economic development in urban environments (Aurigi and Graham 2000). Research by Aurigi (2000) shows that these websites were mainly used to: stimulate local economic development; improve the image of a city; widen access to the Internet and support community networking; support the implementation of online debates, discourses and communities; and improve the management of cities' physical infrastructures.

The digital city movement was very active in Europe, in which many cities have been involved in the construction of their digital counterparts (Aurigi 2000; 2003; Mino 2000). Successful experiences have been identified in Amsterdam (van den Besselaar 2001), Helsinki (de Bruine 2000), Antwerp, Newcastle upon Tyne (Peeters 2000; Firmino 2004), Bologna and Bristol (Aurigi 2003; 2005).

At the beginning of the 21st century, while the world was experiencing the construction of digital cities, the term intelligent city has emerged in research by Komninos (2002; 2006; 2008). Its interpretation is provided in a conference paper which was published in 2006: *"intelligent cities […] are territories with high capacity for learning and innovation, which is built-in to the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management"* (Komninos 2006: 13). According to this definition, the distinguishing feature of intelligent cities is their capacity to exploit ICTs for supporting growth and innovation in urban environments while increasing the problem-solving capability of urban communities (Komninos 2002). Consequently, intelligent cities and digital cities share the same interest for ICT-driven urban development. However, while the former focuses attention on facilitating some aspects of the social and economic life of urban areas, in the latter ICT infrastructures and applications aim at strengthening their ability to produce new knowledge and innovation.

The transition from intelligent to smart seems to be the result of two different forces. On the one hand, there is the technological innovation in the ICT sector that has produced the huge wave of smart objects which are discussed in the cluster mc.02, opening up new possibilities in addressing cities' issues and development priorities using digital technologies (Komninos 2011; Schaffers et al. 2011). On the other hand, there is a request for a more progressive view of ICT-driven urban innovation strategies, which emerges in recent smart city literature (Caragliu et al. 2009; Hollands 2008; Schaffers et al. 2011; Paskaleva 2009; Ratti and Townsend 2011; Townsend et al. 2011; Deakin and Al Wear 2011; Leydesdorff and Deakin 2011) and is supported in the work previously undertaken by Aurigi (2005; 2006), Mino (2000), Graham and Marvin (1999) and Castells (1996).

These authors propose a holistic interpretation of smart cities in which human, social, cultural, environmental, economic and technological aspects stand alongside one another. In this cluster, smart cities are urban areas where ICT is adopted to meet local development needs, be they of social, economic or environmental nature, and the strategies for building smart cities are grounded in collective intelligence, participatory governance, collaboration, community-led urban development, open innovation and user-driven innovation.

5. Discussion and Conclusions

This paper reports on a bibliometric study of the first two decades of research on smart cities (1992-2012) in which co-citation cluster analysis and text-based analysis are combined to map the publications dealing with the smart-city concept and provide a visual representation of their organization. The clusters of publications that are thematically related are then identified and the emerging development paths of smart cities and the strategic perspectives each of them embodies are revealed. The analysis shows five main development paths:

1. Experimental Path, in which smart cities are described as urban testbeds for experimenting Internet of Things infrastructures and service applications and analyzing their functioning, relevance and potential impact in real-life environments;
2. Ubiquitous Path, where smart cities and ubiquitous cities overlap and are considered as two equivalent concepts;
3. Corporate Path, in which urban areas become smart when they are equipped with a platform of digital solutions provided by ICT consultancies;
4. European Path, which represents smart cities as highly efficient urban systems in which digital technologies are used to tackle environmental degradation and fight climate change by transforming buildings, energy networks and transport systems;
5. Holistic Path, where smart cities are considered as urban settlements in which digital technologies are assembled to meet local development needs and their development process is grounded in collective intelligence, participatory governance, collaborative association, community-led urban development and open and user-driven innovation.

By comparing the strategic perspectives for smart-city development that each path stands for, however, divergent choices seem to emerge. This requires future research to produce the scientific knowledge necessary to improve decision-making processes in the field of smart cities:

1. While the Experimental Path, Ubiquitous Path and Corporate Path suggest smart-city development requires a technology-driven and market-oriented approach, the Holistic Path proposes a human-centric and people-driven vision;
2. According to the Corporate Path and Ubiquitous Path, smart-city development needs to be top-down and centralized rather than bottom-up, decentralized and diffused, as the Holistic Path

suggests;

3. The Corporate Path also suggests that smart cities result from a double-helix collaborative model, where IT solution providers try to sell their products to local governments, but the Holistic Path is oriented towards accessing a more open and inclusive collaborative model where university, industry, government and civil society work together;

4. The Holistic Path, Experimental Path, Ubiquitous Path and Corporate Path propose an integrated and multi-dimensional approach to smart-city development, which embraces as many smart-city domains as possible, and is opposed to the mono-dimensional intervention logic of the European Path, that focuses attention only on low-carbon technologies for smart transports, smart buildings and smart grids.

This study systematically captures the division affecting research on smart cities and provides the scientific knowledge necessary to start developing that clear and common understanding of smart cities which is still missing. However, an extension of this bibliometric analysis to the literature published after 2012 would be a relevant research activity for understanding whether and how the scenario represented in this paper and the smart-city development paths it reveals have evolved in relation to the most recently published material.

References

Albino, V., Berardi, U., and Dangelico, R. M. (2015). Smart Cities: Definitions, Dimensions, Performance, and Initiatives. *Journal of Urban Technology,* 22(1), 3–21.

Alkandari, A., Alnasheet, M., and Alshekhly, I. F. (2012). Smart Cities: Survey. *Journal of Advanced Computer Science and Technology Research,* 2(2), 79–90.

Allmayer, S., and Winkler, H. (2013). Interface Management Research in Supplier–customer Relationships: Findings from a Citation Analysis of International Literature. *Journal of Business Economics,* 83(9), 1015–1061.

Amato, V., Bloomer, L., Holmes, A., and Kondepudi, S. (2012a). Government Competitiveness Drives Smart+connected Communities Initiative. White paper. Cisco Systems. http://www.smartconnectedcommunities.org/docs/DOC-2174. Accessed 4 January 2013.

Amato, V., Bloomer, L., Holmes, A., and Kondepudi, S. (2012b). Using ICT to Deliver Benefits to Cities by Enabling Smart+Connected Communities. White paper. Cisco Systems. http://www.smartconnectedcommunities.org/docs/DOC-2150. Accessed 4 January 2013.

Amato, V., Kondepudi, S., and Holmes, A. (2012c). Transforming Communities with Smart+connected Services. White paper. Cisco Systems. http://www.smartconnectedcommunities.org/docs/DOC-2129. Accessed 4 January 2013.

American Association for the Advancement of Science (2001). *AAAS Atlas of Population and Environment.* Oakland, CA: University of California Press.

Anthopoulos, L., and Fitsilis, P. (2010a). From Digital to Ubiquitous Cities: Defining a Common Architecture for Urban Development. In V. Callaghan, A. Kameas, S. Egerton, I. Satoh, and M. Weber (Eds.), *Proceedings 2010 Sixth International Conference on Intelligent Environments (IE), Kuala Lumpur, 19-21 July 2012* (pp. 301-306). Piscataway, NJ: Institute of Electrical and Electronics Engineers (IEEE).

Anthopoulos, L., and Fitsilis, P. (2010b). From Online to Ubiquitous Cities: The Technical Transformation of Virtual Communities. In A. B. Sideridis, and C. Z. Patrikakis (Eds.), *Next Generation Society. Technological and Legal Issues: Third International Conference, E-Democracy 2009, Athens, Greece, September 23–25, 2009, Revised Selected Papers* (pp. 360–372). Berlin: Springer.

Atzori, L., Iera, A., and Morabito, G. (2010). The Internet of Things: A Survey. *Computer Networks,* 54(15), 2787–2805.

Aurigi, A. (2000). Digital City or Urban Simulator? In T. Ishida, and K. Isbister (Eds.), *Digital Cities: Technologies, Experiences and Future Perspectives* (pp. 33–44). Berlin: Springer.

Aurigi, A. (2003). The First Steps of Digital Cities: Development of Social Shaping of Web-based Urban Cyberspace in Europe. Doctoral thesis. University of Newcastle upon Tyne. https://theses.ncl.ac.uk/dspace/handle/10443/506. Accessed 13 May 2014.

Aurigi, A. (2005). Urban Cyberspace as a Social Construction: Non-technological Factors in the

Shaping of Digital Bristol. In P. van den Besselaar, and S. Koizumi (Eds.), *Digital Cities III. Information Technologies for Social Capital: Cross-cultural Perspectives. Third International Digital Cities Workshop, Amsterdam, the Netherlands, September 18-19, 2003. Revised Selected Papers* (pp. 97-112). Berlin: Springer.

Aurigi, A. (2006). New Technologies, Same Dilemmas: Policy and Design Issues for the Augmented City. *Journal of Urban Technology,* 13(3), 5–28.

Aurigi, A., and Graham, S. (2000). Cyberspace and the City: The "virtual City" in Europe. In G. Bridge, and S. Watson (Eds.), *A Companion to the City* (pp. 489-502). Malden, MA: Blackwell Publishing.

Bolici, R., and Mora, L. (2015). Urban Regeneration in the Digital Era: How to Develop Smart City Strategies in Large European Cities. *TECHNE: Journal of Technology for Architecture and Environment,* 5(2), 110–119.

Braam, R. R., Moed, H. F., and van Raan, A. F. J. (1991a). Mapping of Science by Combined Co-citation and Word Analysis. I: Structural Aspects. *Journal of the American Society for Information Science and Technology,* 42(4), 233–251.

Braam, R. R., Moed, H. F., and van Raan, A. F. J. (1991b). Mapping of Science by Combined Co-citation and Word Analysis. II: Dynamical Aspects. *Journal of the American Society for Information Science and Technology,* 42(4), 252–266.

Brech, B., Rajan, R., Fletcher, J., Harrison, C., Hayes, M., Hogan, J., Hopkins, L., Isom, P. K., Meegan, J., Penny, C., Snowdon, J. L., and Wood, D. A. (2011). Smarter Cities Series: Understanding the IBM Approach to Efficient Buildings. IBM Corporation. http://www.redbooks.ibm.com/redpapers/pdfs/redp4735.pdf. Accessed 14 September 2012.

de Bruine, A. (2000). Digital City Bristol: A Case Study. In T. Ishida, and K. Isbister (Eds.), *Digital Cities: Technologies, Experiences and Future Perspectives* (pp. 110–124). Berlin: Springer.

Buscher, V., and Doody, L. (2013). The Smart City Market: Opportunities for the UK. BIS Research Paper n°136. United Kingdom Government - Department for Business, Innovation and Skills. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249423/bis-13-1217-smart-city-market-opportunties-uk.pdf. Accessed 23 January 2014.

Caragliu, A., Del Bo, C., and Nijkamp, P. (2009). Smart Cities in Europe. Paper presented at 3rd Central European Conference in Regional Science, Kosice, 7–9 October 2009. http://www.inta-aivn.org/images/cc/Urbanism/background%20documents/01_03_Nijkamp.pdf. Accessed 29 December 2012.

Castells, M. (1996). *The Rise of the Network Society.* Oxford: Balckwell Publishing Ltd.

Chen-Ritzo, C., Harrison, C., Paraszczak, J., and Parr, F. (2009). Instrumenting the Planet. *IBM Journal of Research and Development,* 53(3), 338–353.

Chourabi, H., Nam, T., Walker, S., Gil-Garcia, R. J., Mellouli, S., Nahon, K., Pardo, T. A., and Scholl, H. J. (2012). Understanding Smart Cities: An Integrative Framework. In R. H. Sprague (Ed.), *Proceedings of the 45th Hawaii International Conference on System Sciences (HICSS), Maui, HI, 04-07 January 2012* (pp. 2289-2297). Piscataway, NJ: Institute of Electrical and Electronics Engineers (IEEE).

Clarke, R. Y. (2013). Smart Cities and the Internet of Everything: The Foundation for Delivering Next-generation Citizen Services. White paper. International Data Corporation (IDC). http://www.cisco.com/web/strategy/docs/scc/ioe_citizen_svcs_white_paper_idc_2013.pdf. Accessed 1 April 2014.

Cosgrove, M., Harthoorn, W., Hogan, J., Jabbar, R., Kehoe, M., Meegan, J., and Nesbitt, P. (2011). Smarter Cties Series: Introducing the IBM City Operations and Management Solution. IBM Corporation. http://www.redbooks.ibm.com/redpapers/pdfs/redp4734.pdf. Accessed 14 September 2012.

de Jong, M., Joss, S., Schraven, D., Zhan, C., and Weijnen, M. (2015). Sustainable-Smart-Resilient-Low Carbon-Eco-Knowledge Cities; Making Sense of a Multitude of Concepts Promoting Sustainable Urbanization. *Journal of Cleaner Production*, 109, 25–38.

Deakin, M. (Ed.) (2013). *Smart Cities: Governing, Modelling and Analysing the Transition.* New York City, NY: Routledge.

Deakin, M., and Al Wear, H. (2011). From Intelligent to Smart Cities. *Intelligent Buildings International,* 3(3), 140–152.

Dirks, S., Gurdgiev, C., and Keeling, M. (2010). Smarter Cities for Smarter Growth: How Cities Can Optimize Their Systems for the Talent-based Economy. Executive report. IBM Corporation. http://public.dhe.ibm.com/common/ssi/ecm/en/gbe03348usen/GBE03348USEN.PDF. Accessed 3 February 2012.

Dirks, S., and Keeling, M. (2009). A Vision of Smarter Cities: How Cities Can Lead the Way into a Prosperous and Sustainable Future. Executive report. IBM Corporation. http://www-03.ibm.com/press/attachments/IBV_Smarter_Cities_-_Final.pdf. Accessed 3 February 2012.

Dirks, S., Keeling, M., and Dencik, J. (2009). How Smart Is Your City: Helping Cities Measure Progress. Executive report. IBM Corporation. http://public.dhe.ibm.com/common/ssi/ecm/en/gbe03248usen/GBE03248USEN.PDF. Accessed 6 June 2014.

Dvir, R., and Pasher, E. (2004). Innovation Engines for Knowledge Cities: An Innovation Ecology Perspective. *Journal of Knowledge Management,* 8(5), 16–27.

European Commission (2006). *European SmartGrids Technology Platform: Vision for Europe's Electricity Networks of the Future.* Belgium: European Union.

European Commission (2009a). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Investing in the Development of Low Carbon Technologies (SET-Plan). COM(2009) 519 final. European Commission. http://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:52009DC0519&from=EN. Accessed 2 February 2014.

European Commission (2009b). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on Mobilising Information and Communication Technologies to Facilitate the Transition to An Energy Efficient, Low-carbon Economy. COM(2009) 111 final. European Commission. http://ec.europa.eu/information_society/activities/sustainable_growth/docs/com_2009_111/com2009-111-en.pdf. Accessed 2 February 2014.

Firmino, R. J. (2004). Building the Virtual City: The Dilemmas of Integrating Strategies for Urban and Electronic Spaces. PhD thesis. University of Newcastle upon Tyne. http://www.academia.edu/1112229/Building_the_virtual_city_the_dilemmas_of_integrating_strategies_for_urban_and_electronic_spaces. Accessed 1 September 2014.

Florida, R. (2002). *The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life.* New York City, NY: Basic Books.

Florida, R. (2005). *Cities and the Creative Class.* New York City, NY: Routledge.

Gil-Castineira, F., Costa-Montenegro, E., Francisco J., G., Lopez-Bravo, C., Ojala, T., and Bose, R. (2011). Experiences Inside the Ubiquitous Oulu Smart City. *Computer,* 44(6), 48–55.

Glanzel, W., and Czerwon, H. J. (1996). A New Methodological Approach to Bibliographic Coupling and Its Application to the National, Regional and Institutional Level. *Scientometrics,* 37(2), 195-221.

Glanzel, W., and Thijs, B. (2011). Using 'core Documents' for the Representation of Clusters and Topics. *Scientometrics,* 88(1), 297-309.

Gmur, M. (2003). Co-citation Analysis and the Search for Invisible Colleges: A Methodological Evaluation. *Scientometrics,* 57(1), 27–57.

Graham, S. (2004a). Introduction: From Dreams of Transcendence to the Remediation of Urban Life. In S. Graham (Ed.), *The Cybercities Reader* (pp. 1-29). New York, United States: Routledge.

Graham, S. (Ed.) (2004b). *The Cybercities Reader.* New York City, NY: Routledge.

Graham, S., and Marvin, S. (1996). *Telecommunications and the City: Electronic Spaces, Urban Places.* New York City, NY: Routledge.

Graham, S., and Marvin, S. (1999). Planning Cyber-cities? Integrating Telecommunications Into Urban Planning. *Town Planning Review,* 70(1), 89-114.

Graham, S., and Marvin, S. (2001). *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition.* New York City, NY: Routledge.

GSMA (2012). South Korea: Busan Green U-City. Report. GSMA. http://www.gsma.com/connectedliving/wp-content/uploads/2012/08/cl_busan_08_121.pdf. Accessed 20 June 2013.

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., and Williams, P. (2010). Foundations for Smarter Cities. *IBM Journal of Research and Development,* 54(4), 1-16.

Harrison, C., Paraszczak, J., and Williams, R. P. (2011). Preface: Smarter Cities. *IBM Journal of Research and Development,* 55(1-2), 1–5.

Hollands, R. G. (2008). Will the Real Smart City Please Stand Up? *City: analysis of urban trends, culture, theory, policy, action,* 12(3), 303-320.

Hollands, R. G. (2015). Critical Interventions into the Corporate Smart City. *Cambridge Journal of Regions, Economy and Society,* 8(1), 61-77.

Hollands, R. G. (2016). Beyond the Corporate Smart City? Glimpses of Other Possibilities of Smartness. In S. Marvin, A. Luque-Ayala, and C. McFarlane (Eds.), *Smart Urbanism: Utopian Vision or False Dawn?* (pp. 168-184). New York City, NY: Routledge.

Holler, J., Tsiatsis, V., Avesand, S., Karnouskos, S., and Boyle, D. (2014). *From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence.* Oxford: Elsevier.

IBM Corporation (2011). City of Rio De Janeiro and IBM Collaborate to Advance Emergency Response System. Press release. IBM Corporation. http://www-03.ibm.com/press/us/en/pressrelease/35945.wss. Accessed 12 October 2012.

IBM Corporation (2017). IBM Smarter Planet. Website. http://www.ibm.com/smarterplanet. Accessed 15 February 2015.

Ingwersen, P., Larsen, B., Garcia-Zorita, J. C., Serrano-Lopez, A. E., and Sanz-Casado, E. (2014). Influence of Proceedings Papers on Citation Impact in Seven Sub-fields of Sustainable Energy Research 2005–2011. *Scientometrics,* 101(2), 1273-1292.

ITU (2005). ITU Internet Reports 2005: The Internet of Things. Report. International Telecommunication Union. http://www.itu.int/osg/spu/publications/internetofthings/. Accessed 4 June 2014.

Ishida, T., and Isbister, K. (Eds.) (2000). *Digital Cities: Technologies, Experiences and Future Perspectives.* Berlin: Springer.

Juan, Y. K., Wang, L., Wang, J., Leckie, J., and Li, K. M. (2011). A Decision-support System for Smarter City Planning and Management. *IBM Journal of Research and Development,* 55(1-2), 3:1-3:12.

Karnouskos, S., and Nass de Holanda, T. (2009). Simulation of a Smart Grid City with Software Agents. In *EMS '09: Third UKSim European Symposium on Computer Modeling and Simulation, Athens, 25-27 November 2009* (pp. 424-429). Piscataway, NJ: Institute of Electrical and Electronics Engineers (IEEE).

Katz, J. S., and Ruano, J. (2011). Smarter Cities Series: Understanding the IBM Approach to Energy Innovation. IBM Corporation. http://www.redbooks.ibm.com/redpapers/pdfs/redp4739.pdf. Accessed 14 September 2012.

Kehoe, M., Cosgrove, M., De Gennaro, S., Harrison, C., Harthoorn, W., Hogan, J., Meegan, J., Nesbitt, P., and Peters, C. (2011). Smarter Cities Series: A Foundation for Understanding IBM Smarter Cities. IBM Corporation. http://www.redbooks.ibm.com/redpapers/pdfs/redp4733.pdf. Accessed 14 September 2012.

Kitchin, R. (2014). The Real-time City? Big Data and Smart Urbanism. *GeoJournal,* 79(1), 1-14.

Kohno, M., Masuyama, Y., Kato, N., and Tobe, A. (2011). Hitachi's Smart City Solutions for New Era of Urban Development. *Hitachi Review,* 60(2), 79-88.

Komninos, N. (2002). *Intelligent Cities: Innovation, Knowledge, Systems and Digital Spaces.* New York City, NY: Spon Press.

Komninos, N. (2006). The Architecture of Intelligent Cities: Integrating Human, Collective and Artificial Intelligence to Enhance Knowledge. In *Proceedings of the 2nd IET International Conference on*

Intelligent Environments, Athens, 05-06 July 2006 (pp. 13-20). Norwich: Page Bros Ltd.

Komninos, N. (2008). *Intelligent Cities and Globalization of Innovation Networks.* New York City, NY: Routledge.

Komninos, N. (2011). Intelligent Cities: Variable Geometries of Spatial Intelligence. *Intelligent building international,* 3(3), 172-188.

Komninos, N. (2014). *The Age of Intelligent Cities: Smart Environments and Innovation-for-all Strategies.* New York City, NY: Routledge.

Komninos, N., and Mora, L. (2018). Exploring the Big Picture of Smart City Research. *Scienze Regionali: Italian Journal of Regional Science, 1 (2018)*

Kurebayashi, T., Masuyama, Y., Morita, K., Taniguchi, N., and Mizuki, F. (2011). Global Initiatives for Smart Urban Development. *Hitachi Review,* 60(2), 89–93.

Landry, C. (2000). *The Creative City: A Toolkit for Urban Innovation.* London: Earthscan.

Lazaroiu, G. C., and Roscia, M. (2012). Definition Methodology for the Smart Cities Model. *Energy,* 47(1), 326–332.

Lee, S., Han, J., Leem, Y., and Yigitcanlar, T. (2008). Towards Ubiquitous City: Concept, Planning, and Experiences in the Republic of Korea. In T. Yigitcanlar, K. Velibeyoglu, and S. Baum (Eds.), *Knowledge-based Urban Development: Planning and Applications in the Information Era* (pp. 148–169). Hershey, PA: IGI Global.

Leydesdorff, L., and Deakin, M. (2011). The Triple-helix Model of Smart Cities: A Neo-evolutionary Perspective. *Journal of Urban Technology*, 18(2), 53–63.

McNeill, D. (2016). IBM and the Visual Formation of Smart Cities. In S. Marvin, A. Luque-Ayala, and C. McFarlane (Eds.), *Smart Urbanism: Utopian Vision or False Dawn?* (pp. 34-51). New York City, NY: Routledge.

Meijer, A., and Bolivar, M. P. R. (2016). Governing the Smart City: A Review of the Literature on Smart Urban Governance. *International Review of Administrative Sciences,* 82(2), 392–408.

Meyer, M., Libaers, D., Thijs, B., Grant, K., Glanzel, W., and Debackere, K. (2013). Origin and Emergence of Entrepreneurship as a Research Field. *Scientometrics,* 98(1), 473–485.

Mino, E. (2000). Experiences of European Digital Cities. In T. Ishida, and K. Isbister (Eds.), *Digital Cities: Technologies, Experiences and Future Perspectives* (pp. 58-72). Berlin: Springer.

Miorandi, D., Sicari, S., De Pellegrini, F., and Chlamtac, I. (2012). Internet of Things: Vision, Applications and Research Challenges. *Ad Hoc Networks,* 10(7), 1497-1516.

Mitchell, W. J. (1995). *The City of Bits: Space, Place, and the Infobahn.* Cambridge, MA: The MIT Press.

Mitchell, W. J. (1999). *E-topia: Urban Life, Jim--but Not as We Know It.* Cambridge, MA: The MIT Press.

Mitchell, W. J. (2003). *Me++: The Cyborg Self and the Networked City.* Cambridge, MA: The MIT Press.

Mora, L., and Bolici, R. (2016). The Development Process of Smart City Strategies: The Case of Barcelona. In J. Rajaniemi (Ed.), *Re-City: Future City - Combining Disciplines* (pp. 155-181). Tampere: Juvenes print.

Mora, L., and Bolici, R. (2017). How to Become a Smart City: Learning from Amsterdam. In A. Bisello, D. Vettorato, R. Stephens, and P. Elisei (Eds.), *Smart and Sustainable Planning for Cities and Regions: Results of SSPCR 2015* (pp. 251-266). Cham: Springer.

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), 3-27.

Moss Kanter, R., and Litow, S. S. (2009). Informed and Interconnected: A Manifesto for Smarter Cities. Working paper. Harvard Business School. http://www.hbs.edu/faculty/Publication%20Files/09-141.pdf. Accessed 24 January 2012.

Nam, T., and Pardo, T. A. (2011a). Conceptualizing Smart City with Dimensions of Technology, People and Institutions. In J. Bertot, K. Nahon, S. A. Chun, L. Luna-Reyes, and V. Atluri (Eds.), *Proceedings of the 12th Annual International Conference on Digital Government Research: Digital Government Innovation in Challenging Times, College Park, MD, 12-15 June 2011* (pp. 282-291). New York City,

NY: ACM Press.

Nam, T., and Pardo, T. A. (2011b). Smart City as Urban Innovation: Focusing on Management, Policy, and Context. In E. Estevez, and M. Janssen (Eds.), *Proceedings of the 5th International Conference on Theory and Practice of Electronic Governance (ICEGOV2011), Tallinn, 26–28 September 2011* (pp. 185-194). New York City, NY: ACM Press.

Naphade, M., Banavar, G., Harrison, C., Paraszczak, J., and Morris, R. (2011). Smarter Cities and Their Innovation Challenges. *Computer,* 44(6), 32–39.

Palmisano, S. J. (2008). A Smarter Planet: The Next Leadership Agenda. Speech. IBM Corporation. www.ibm.com/ibm/blf/pdf/SJP_Smarter_Planet.pdf. Accessed 3 March 2011.

Paskaleva, K. A. (2009). Enabling the Smart City: The Progress of City E-governance in Europe. *International Journal of Innovation and Regional Development,* 1(4), 405-422.

Paskaleva, K. A. (2011). The Smart City: A Nexus for Open Innovation? *Intelligent building international,* 3(3), 133–152.

Paul, A., Cleverley, M., Kerr, W., Marzolini, F., Reade, M., and Russo, S. (2011). Smarter Cities Series: Understanding the IBM Approach to Public Safety. IBM Corporation. http://www.redbooks.ibm.com/redpapers/pdfs/redp4738.pdf. Accessed 14 September 2012.

Peeters, B. (2000). The Information Society in the City of Antwerp. In T. Ishida, and K. Isbister (Eds.), *Digital Cities: Technologies, Experiences and Future Perspectives* (pp. 73–82). Berlin: Springer.

Polastre, J., Hill, J., and Culler, D. (2004). Versatile Low Power Media Access for Wireless Sensor Networks. In *SenSys '04: Proceedings of the 2nd International Conference on Embedded Networked Sensor Systems, Baltimore, MD, 3-5 November 2004* (pp. 95–107). New York City, NY: ACM Press.

Ratti, C., and Townsend, A. (2011). The Social Nexus. *Scientific American,* September 2011, 42-48.

Republic of Korea (2007a). U-city. Brochure. Republic of Korea. http://eng.nia.or.kr/english/bbs/download.asp?fullpathname=%5CData%5Cattach%5C20111222161 1231975%5Cu-City(2007).pdf&filename=u-City(2007).pdf. Accessed 6 September 2014.

Republic of Korea (2007b). U-Korea Master Plan: To Achieve the World First Ubiquitous Society. Republic of Korea. http://www.ipc.go.kr/servlet/download?pt=/ipceng/publicandfn=u-KOREA+Master+Plan+.pdf. Accessed 6 September 2014.

Ruano, J., Chao, T., Hartswick, P., Havers, B., Meegan, J., Wasserkrug, S., and Williams, P. (2011). Smarter Cities Series: Understanding the IBM Approach to Water Management. IBM Corporation. http://www.redbooks.ibm.com/redpapers/pdfs/redp4736.pdf. Accessed 14 September 2012.

Sanchez, L., Galache, J. A., Gutierrez, V., Hernandez, J. M., Bernat, J., Gluhak, A., and Garcia, T. (2011). SmartSantander: The Meeting Point Between Future Internet Research and Experimentation and the Smart Cities. In P. Cunningham, and M. Cunningham (Eds.), *Future Network & Mobile Summit 2011 Conference Proceedings, Warsaw, 15-17 June 2011* (pp. 1-8). Piscataway, NJ: Institute of Electrical and Electronics Engineers (IEEE).

Sanchez, L., Gutierrez, V., Galache, J. A., Sotres, P., Santana, J. R., Casanueva, J., and Munoz, L. (2013). SmartSantander: Experimentation and Service Provision in the Smart City. In *2013 16th International Symposium on Wireless Personal Multimedia Communications (WPMC), Atlantic City, NJ, 24-27 June 2013* (pp. 1-6). Piscataway, NJ: Institute of Electrical and Electronics Engineers (IEEE).

Schaefer, S., Harrison, C., Lamba, N., and Srikanth, V. (2011). Smarter Cities Series: Understanding the IBM Approach to Traffic Management. IBM Corporation. http://www.redbooks.ibm.com/redpapers/pdfs/redp4737.pdf. Accessed 14 September 2012.

Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M., and Oliveira, A. (2011). Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation. In J. Domingue, A. Galis, A. Gavras, T. Zahariadis, D. Lambert, F. Cleary, P. Daras, S. Krco, H. Muller, M. Li, H. Schaffers, V. Lotz, F. Alvarez, B. Stiller, S. Karnouskos, S. Avessta, and M. Nillson (Eds.), *The Future Internet. Future Internet Assembly 2011: Achievements and Technological Promises* (pp. 431-446). Berlin: Springer.

Schneider, J. W., Larsen, B., and Ingwersen, P. (2009). A Comparative Study of First and All-author

Co-citation Counting, and Two Different Matrix Generation Approaches Applied for Author Co-citation Analyses. *Scientometrics,* 80(1), 1053-1320.

Schopfel, J., and Farace, D. J. (2010). Grey Literature. In M. J. Bates, and M. N. Maack (Eds.), *Encyclopedia of Library and Information Sciences* (pp. 2029–2039). New York City, NY: Taylor & Francis.

Schopfel, J. (2010). Towards a Prague Definition of Grey Literature. In D. J. Farace, and J. Fratzen (Eds.), *Twelfth International Conference on Grey Literature: Transparency in Grey Literature. Grey Tech Approaches to High Tech Issues, Prague, 6-7 December 2010* (pp. 11-26). Amsterdam: TextRelease.

Shiau, W., and Dwivedi, Y. K. (2013). Citation and Co-citation Analysis to Identify Core and Emerging Knowledge in Electronic Commerce Research. *Scientometrics,* 94(3), 1317-1337.

Shin, D. (2007). A Critique of Korean National Information Strategy: Case of National Information Infrastructures. *Government Information Quarterly,* 24(3), 624-645.

Shin, D. (2009). Ubiquitous City: Urban Technologies, Urban Infrastructure and Urban Informatics. *Journal of Information Science,* 35(5), 515-526.

Shin, D. (2010). A Realization of Pervasive Computing: Ubiquitous City. In D. F. Kocaoglu, T. R. Anderson, and T. U. Daim (Eds.), *2010 Proceedings of PICMET '10: Technology Management for Global Economic Growth, Seoul, 18-22 July 2010* (pp. 1-10). Piscataway, NJ: Institute of Electrical and Electronics Engineers (IEEE).

Shin, D., and Kim, T. (2010). Large-scale ICT Innovation and Policy. In D. F. Kocaoglu, T. R. Anderson, T. U. Daim, A. Jetter, and C. M. Weber (Eds.), *PICMET 2010 Proceedings: Technology Management for Global Economic Growth, Seoul, 18–22 July 2010* (pp. 148-161). Piscataway, NJ: Institute of Electrical and Electronics Engineers (IEEE).

Shin, D., and Lee, C. (2011). Disruptive Innovation for Social Change: How Technology Innovation Can Be Best Managed in Social Context. *Telematics and Informatics,* 28(2), 86-100.

Shwayri, S. T. (2013). A Model Korean Ubiquitous Eco-city? The Politics of Making Songdo. *Journal of Urban Technology,* 20(1), 39-55.

Singer, N. (2012). Mission Control, Built for Cities: IBM Takes 'Smarter Cities' Concept to Rio De Janeiro. Online article. The New York Times. http://www.nytimes.com/2012/03/04/business/ibm-takes-smarter-cities-concept-to-rio-de-janeiro.html?pagewanted=all&_r=0. Accessed 12 October 2012.

Small, H. G., and Crane, D. (1979). Specialties and Disciplines in Science and Social Science: An Examination of Their Structure Using Citation Indexes. *Scientometrics,* 1(5-6), 445-461.

Soderstrom, O., Paasche, T., and Klauser, F. (2014). Smart Cities as Corporate Storytelling. *City: analysis of urban trends, culture, theory, policy, action,* 18(3), 307-320.

Strickland, E. (2011). Cisco Bets on South Korean Smart City. *IEEE Spectrum,* 48(8), 11–12.

Sundmaeker, H., Guillemin, P., Friess, P., and Woelfflé, S. (Eds.) (2010). *Vision and Challenges for Realising the Internet of Things.* Brussels: European Commission.

Tamai, H. (2014). Fujitsu's Approach to Smart Cities. *FUJITSU Scientific and Technical Journal,* 50(2), 3-10.

Tekes (2011). Ubiquitous City in Korea: Services and Enabling Technologies. Report. Tekes. https://www.tekes.fi/globalassets/global/ohjelmat-ja-palvelut/ohjelmat/ubicom/aineistot/raportit/korea/ubiquitouscityinkorea.pdf. Accessed 15 May 2014.

The Climate Group (2008). SMART 2020: Enabling the Low Carbon Economy in the Information Age. Report. The Climate Group. http://www.smart2020.org/_assets/files/02_Smart2020Report.pdf. Accessed 5 June 2014.

Townsend, A. (2013). *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia.* New York City, NY: W.W. Norton & Company Ltd.

Townsend, A., Maguire, R., Liebhold, M., and Crawford, M. (2011). A Planet of Civic Laboratories: The Future of Cities, Information and Inclusion. White paper. Institute for the Future.

http://www.iftf.org/uploads/media/IFTF_Rockefeller_CivicLaboratoriesMap_01.pdf. Accessed 8 December 2011.

Tselentis, G., Domingue, J., Galis, A., Gavras, A., Hausheer, D., Krco, H., Lotz, V., and Zahariadis, T. (Eds.) (2009). *Towards the Future Internet: A European Research Perspective.* Amsterdam: IOS Press.

United Nations Human Settlements Programme (2011). *Cities and Climate Change: Global Report on Human Settlements 2011.* London: Earthscan.

US Department of Commerce - NIST (2010). NIST Framework and Roadmap for Smart Grid Interoperability Standards. Report. National Institute of Standards and Technology - US Department of Commerce. http://www.nist.gov/public_affairs/releases/upload/smartgrid_interoperability_final.pdf. Accessed 30 September 2014.

van den Besselaar, P. (2001). E-community Versus E-commerce: The Rise and Decline of the Amsterdam Digital City. *AI & Society: Knowledge, Culture and Communication,* 15(3), 280–288.

Washburn, D., Usman, S., Balaouras, S., Dines, R. A., Hayes, N. M., and Nelson, L. E. (2010). Helping CIOs Understand "Smart City" Initiatives. White paper. Forrester Research. http://www.forrester.com/Helping+CIOs+Understand+Smart+City+Initiatives/quickscan/-/E-RES55590. Accessed 20 March 2012.

Weiser, M. (1991). The Computer for the 21st Century. *Mobile Computing and Communications Review,* 3(3), 3-11.

Weiser, M. (1993). Hot Topics: Ubiquitous Computing. *Computer,* 26(10), 71–72.

Weiser, M., Gold, R., and Brown, J. S. (1999). The Origins of Ubiquitous Computing Research at PARC in the Late 1980s. *IBM System Journal,* 38(4), 693-696.

Yigitcanlar, T., and Lee, S. H. (2014). Korean Ubiquitous-eco-city: A Smart-sustainable Urban Form or a Branding Hoax? *Technological Forecasting & Social Change,* 89, 100-114.

Yigitcanlar, T., O'Connor, K., and Westerman, C. (2008a). The Making of Knowledge Cities: Melbourne's Knowledge-based Urban Development Experience. *Cities,* 25(2), 63-72.

Yigitcanlar, T., Velibeyoglu, K., and Baum, S. (Eds.) (2008b). *Creative Urban Regions: Harnessing Urban Technologies to Support Knowledge City Initiatives.* Hershey, PA: IGI Global.

Yigitcanlar, T., Velibeyoglu, K., and Baum, S. (Eds.) (2008c). *Knowledge-based Urban Development: Planning and Applications in the Information Era.* Hershey, PA: IGI Global.

Yigitcanlar, T., Velibeyoglu, K., and Martinez-Fernandez, C. (2008d). Rising Knowledge Cities: The Role of Urban Knowledge Precincts. *Journal of Knowledge Management,* 12(5), 8-20.

Yoshikawa, Y., Tada, K., Furuya, S., and Koda, K. (2011). Actions for Realizing Next-generation Smart Cities. *Hitachi Review,* 60(6), 89-93.

Zanella, A., Bui, N., Castellani, A., Vangelista, L., and Zorzi, M. (2014). Internet of Things for Smart Cities. *IEEE Internet of Things Journal,* 1(1), 22-32.

Zygiaris, S. (2013). Smart City Reference Model: Assisting Planners to Conceptualize the Building of Smart City Innovation Ecosystems. *Journal of the Knowledge Economy,* 4(2), 217-231.

Appendix A

CLUSTER	SIZE			DEGREE OF CENTRALITY
	n° publications	% on total	n° source doc.	
mc.01	57	2.5%	0	2,944
mc.02	**578**	**25.4%**	**18**	**15,435**
mc.03	25	1.1%	0	449
mc.04	26	1.1%	0	461
mc.05	**306**	**13.5%**	**9**	**16,446**
mc.06	78	3.4%	1	1,811
mc.07	109	4.8%	4	4,636
mc.08	**283**	**12.4%**	**35**	**11,373**
mc.09	56	2.5%	1	1,400
mc.10	6	0.3%	0	30
mc.11	21	0.9%	0	382
mc.12	3	0.1%	0	6
mc.13	6	0.3%	0	30
mc.14	**261**	**11.5%**	**22**	**4,120**
mc.15	13	0.6%	1	183
mc.16	58	2.6%	1	2,710
mc.17	**324**	**14.2%**	**32**	**24,206**
mc.18	63	2.8%	0	4,446
Total	2,273		124	

Table 1: Thematic clusters' size and degree of centrality. Main clusters are in bold

CLUSTER	CORE DOCUMENT		Year	Type	In-Degree
	Reference	Title			
mc.02	Weiser (1991)	The computer for the 21st century	1991	Art	185
mc.02	**Atzori et al. (2010)**	**The Internet of Things: a survey**	**2010**	**Art**	**100**
mc.02	Polastre et al. (2004)	Versatile low power media access for wireless sensor networks	2004	Conf	97
mc.02	ITU (2005)	ITU Internet Reports 2005: the Internet of Things	2005	Gr	90
mc.02	Sundmaeker et al. (2010)	Vision and challenges for realising the Internet of Things	2010	Bo	86
mc.05	Florida (2002)	The rise of the creative class: and how it's transforming work, leisure, community and everyday life	2002	Bo	157
mc.05	Landry (2000)	The creative city: a toolkit for urban innovation	2000	Bo	157
mc.05	Yigitcanlar et al. (2008b)	Creative urban regions: harnessing urban technologies to support knowledge city initiatives	2008	Bo	124
mc.05	Yigitcanlar et al. (2008c)	Knowledge-based urban development: planning and applications in the information era	2008	Bo	120
mc.05	Florida (2005)	Cities and the creative class	2005	Bo	106
mc.08	**Dirks et al. (2010)**	**Smarter cities for smarter growth: how cities can optimize their systems for the talent-based economy**	**2010**	**Gr**	**100**

mc.08	Moss Kanter and Litow (2009)	Informed and interconnected: a manifesto for smarter cities	2009	Gr	90
mc.08	Dirks and Keeling (2009)	A vision of smarter cities: how cities can lead the way into a prosperous and sustainable future	2009	Gr	84
mc.08	Harrison et al. (2010)	Foundations for smarter cities	2010	Art	81
mc.08	Washburn et al. (2010)	Helping CIOs understand "Smart City" initiatives	2010	Gr	80
mc.14	European Commission (2006)	European SmartGrids Technology Platform: vision for Europe's electricity networks of the future	2006	Bo	47
mc.14	US Department of Commerce - NIST (2010)	NIST framework and roadmap for smart-grid interoperability standards	2010	Grey	37
mc.14	Karnouskos and Nass de Holanda (2009)	Simulation of a smart-grid city with software agents	2009	Conf	34
mc.14	The Climate Group (2008)	SMART 2020: enabling the low carbon economy in the information age	2008	Gr	28
mc.14	European Commission (2009a)	Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Investing in the development of low carbon technologies (SET-Plan)	2009	Gr	26
mc.17	Komninos (2002)	Intelligent cities: innovation, knowledge, systems and digital spaces	2002	Bo	194
mc.17	Caragliu et al. (2009)	Smart cities in Europe	2009	Conf	180
mc.17	Ishida and Isbister (2000)	Digital cities: technologies, experiences, and future perspectives	2000	Bo	170
mc.17	Komninos (2006)	The architecture of intelligent cities: integrating human, collective and artificial intelligence to enhance knowledge and innovation	2006	Conf	162
mc.17	Graham (2004b)	The cybercities reader	2004	Bo	160

Table 2: Core documents. Source documents are in bold. Bo: books; Art: articles published in scholarly journals; Conf: conference papers; Gr: grey literature.

CLUSTER	WORD PROFILE
mc.02	**INFORMATION TECHNOLOGY** (fr. 1998 - oc. 100,0%); **INTERNET OF THING** (fr. 1433 - oc. 38,9%); **UBIQUITOUS COMPUTING** (fr. 517 - oc. 38,9%); **INFORMATION AND COMMUNICATION TECHNOLOGY** (fr. 494 - oc. 38,9%); **SENSOR NETWORK** (fr. 215 - oc. 61,1%); **MOBILE DEVICE** (fr. 175 - oc. 44,4%); **MOBILE PHONE** (fr. 171 - oc. 55,6%); **RFID TAG** (fr. 136 - oc. 33,3%); **SMART CITY** (fr. 128 - oc. 100,0%); **WIRELESS SENSOR** (fr. 116 - oc. 61,1%)
mc.05	**INFORMATION TECHNOLOGY** (fr. 293 - oc. 100,0%); **INFORMATION AND COMMUNICATION TECHNOLOGY** (fr. 157 - oc. 77,8%); **KNOWLEDGE CITY** (fr. 73 - oc. 55,6%); **URBAN DEVELOPMENT** (fr. 55 - oc. 66,7%); **LOCAL GOVERNMENT** (fr. 47 - oc. 66,7%); **ECONOMIC DEVELOPMENT** (fr. 46 - oc. 66,7%); **SMART CITY** (fr. 39 - oc. 100,0%); **URBAN INFRASTRUCTURE** (fr. 39 - oc. 44,4%); **UBIQUITOUS COMPUTING** (fr. 27 - oc. 33,3%); **KNOWLEDGE ECONOMY** (fr. 25 - oc. 55,6%)
mc.08	**INFORMATION TECHNOLOGY** (fr. 2265 - oc. 100,0%); **SMART CITY** (fr. 838 - oc. 100,0%); **INFORMATION AND COMMUNICATION TECHNOLOGY** (fr. 354 - oc. 62,9%); **DIGITAL CITY** (fr. 235 - oc. 34,3%); **LOCAL GOVERNMENT** (fr. 87 - oc. 45,7%); **QUALITY OF LIFE** (fr. 79 - oc. 48,6%); **SMARTER CITY** (fr. 68 - oc. 31,4%); **CITY INFRASTRUCTURE** (fr. 56 - oc. 31,4%); **PUBLIC SERVICE** (fr. 55 - oc. 48,6%); **URBAN DEVELOPMENT** (fr. 50 - oc. 37,1%)

mc.14	**INFORMATION TECHNOLOGY** (fr. 642 - oc. 100,0%); **INFORMATION AND COMMUNICATION TECHNOLOGY** (fr. 471 - oc. 73,9%); **SMART CITY** (fr. 307 - oc. 100,0%); **ENERGY EFFICIENCY** (fr. 129 - oc. 56,5%); **SMART GRID** (fr. 105 - oc. 52,2%); **CLIMATE CHANGE** (fr. 84 - oc. 34,8%); **ENERGY CONSUMPTION** (fr. 70 - oc. 60,9%); **URBAN DEVELOPMENT** (fr. 63 - oc. 30,4%); **SMART METER** (fr. 55 - oc. 56,5%); **RENEWABLE ENERGY** (fr. 51 - oc. 34,8%)
mc.17	**INFORMATION TECHNOLOGY** (fr. 2056 - oc. 96,9%); **SMART CITY** (fr. 1148 - oc. 100,0%); **INTELLIGENT CITY** (fr. 586 - oc. 53,1%); **INFORMATION AND COMMUNICATION TECHNOLOGY** (fr. 426 - oc. 78,1%); **LIVING LAB** (fr. 296 - oc. 46,9%); **DIGITAL CITY** (fr. 280 - oc. 37,5%); **INNOVATION SYSTEM** (fr. 273 - oc. 34,4%); **INTERNET OF THING** (fr. 161 - oc. 31,3%); **SOCIAL CAPITAL** (fr. 129 - oc. 40,6%); **URBAN DEVELOPMENT** (fr. 98 - oc. 59,4%)

Table 3: Word profiles. Frequency (fr.): number of times the keyword appears in the cluster's source documents; Occurrence (oc.): percentage of cluster's source documents in which the keyword is included.