Understanding the smart city Domain: A Literature Review

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Abstract

Smart Cities appeared in literature in late ‘90s and various approaches have been developed so far. Until today, smart city does not describe a city with particular attributes but it is used to describe different cases in urban spaces: web portals that virtualize cities or city guides; knowledge bases that address local needs; agglomerations with Information and Communication Technology (ICT) infrastructure that attract business relocation; metropolitan-wide ICT infrastructures that deliver e-services to the citizens; ubiquitous environments; and recently ICT infrastructure for ecological use. Researchers, practicians, businessmen and policy makers consider smart city from different perspectives and most of them agree on a model that measures urban economy, mobility, environment, living, people and governance. On the other hand, ICT and construction industries stress to capitalize smart city and a new market seems to be generated in this domain. This chapter aims to perform a literature review, discover and classify the particular schools of thought, universities and research centres as well as companies that deal with smart city domain and discover alternative approaches, models, architecture and frameworks with this regard.

Keywords: smart city, literature review, models, frameworks, architectures, smart growth, digital city.

1. Introduction

Although smart city term has appeared since 1998 (Van Bastelaer, 1998), it is still confusing with regard to its meaning and context (Anthopoulos & Fitsilis, 2013), since its definition ranges from mesh metropolitan information and communications technologies (ICT) environments (Mahizhnan, 1999); to various ICT attributes in a city (Chourabi et al., 2012; Allwinkle & Cruickshank, 2011); to urban living labs (Komninos, 2002); or to the "smartness footprint" of a city, which is measured with indexes such as, the education level of its inhabitants, the innovative spirit of its enterprises etc. (Giffinger et al., 2007). The smart city term appeared early in literature in 1998 (Van Bastelaer, 1998; Mahizhnan, 1999) from urban simulations and knowledge bases and is still evolving to eco-cities (Anthopoulos & Fitsilis, 2013).

All these different meanings address the scale and complexity of the smart city domain and describe alternative approaches, schools of thought and researchers who deal with this phenomenon. Furthermore, smart cities have attracted the international attention by international organizations (i.e., the European Union (Anthopoulos & Fitsilis, 2013)) and big vendors from the ICT industry (i.e., CISCO (2011), IBM (IBM Institute for Business Value, 2009) and Alcatel (Alcatel-Lucent, 2012)); the electronics (i.e., Hitachi (2013)); and construction industries (i.e., GALE, POSCO and HGC Group (Alcatel-Lucent, 2012)) are stressed to develop respective products and to utilize this emerging market. To this end, this chapter aims to answer the following question: "What fundamental theories, models, and concepts in research (published between 1998 and 2014) reflect phenomena related to smart city?" This question is crucial to be answered since interdisciplinary studies investigate the smart city and view this topic from different perspectives.

In order to answer the above question, this chapter was inspired by Niehaves (2011) methodology for performing a holistic literature review and analyzes different sources that investigates smart city and uses some of its context. This analysis attempts to identify authors, schools, approaches, case studies; classifies research projects and business products; and generates a taxonomy that can clarify this complex domain. To this end, the remaining of this chapter is organized as follows:

section 2 examines the relevant general literature on smart cities, while methods and data on this theme are set out. Section 3 summarizes on literature findings, while section 4 contains some conclusions and future thoughts.

2. Background

Various scholars have stressed the smart city term since its initially appearance in 1998 (Van Bastelaer, 1998) and attempted to analyze its context (Anthopoulos and Fitsilis, 2013; Chourabi et al., 2012; Neirotti et al., 2014; Caragliou et al. 2011; Kuk & Janssen, 2011). This chapter extends these approaches and findings with a methodological literature review, which is inspired by Niehaves (2011). In this section, the challenges with regard to the smart city domain are analyzed. Subsequently, the literature search strategy is defined and the corresponding review is performed in order for this paper's research question to be answered. A rigorous literature study requires defining (a) the domain (the disciplinary field in which the literature search is conducted), (b) the sources (publication outlets from that domain to be included in the search), and (c) the search strategy (search terms applied in order to extract relevant articles).

a) Domain: this chapter's goal is to examine smart city research. In this respect, a smart city has been defined with alternative approaches, which range from ICT attributes in the city (i.e., digital, broadband, wireless etc.) that describe various ICT solutions in the urban space and prioritized differently across the Globe (Anthopoulos and Fitsilis, 2013); to the "smartness footprint" in an agglomeration area, which is measured with various indexes (Giffinger et al., 2007); to information flows across the urban space (Stock, 2011); and to large-scale to living labs (Komninos, 2002). With this respect, the smart city can be viewed broadly and concerns interdisciplinary studies (Anthopoulos and Fitsilis, 2013; Anthopoulos and Vakali, 2012) such as, ICT; urban planning and growth; living labs as large-scale testing beds; eco or green city and corresponding ecological aspects; and creative industry in a city. All the above scientific areas appear to "meet" in smart city and various outcomes are generated.

b) Sources: Therefore, as primary sources for this literature review (Phase 1), the following bundles of publication outlets were selected: first, those from journals that publish corresponding works; second, those from major conferences that publish in their proceedings articles relative to smart city; reports from research projects, which have

been or are being developed in this domain; corresponding PhD dissertations; research projects funded by the European Framework Programmes (FPs); and business products. Volumes from 1998 –when the first articles appear- to today were included. Journal selection was based on editorial policy conformity with smart city, as well as the criteria that they publish currently (resp. 2014) and have a high level of scholarly recognition (Saunders et al., 2006).

In this study, an initial search for source identification was conducted in SCOPUS, Science Direct and Google Scholar. The queries that were used contained 'smart city' and relevant terms (i.e., 'digital city', 'ubiquitous city' etc.) that were identified by Anthopoulos and Fitsilis (2013) as smart city classification areas (Table 1).

Term	SCOPUS	Science Direct	Google Scholar
Smart city	616	198	389
Digital city	448	188	405
Virtual city / information city	331 / 43	264 / 74	239 / 33
Knowledge based city	10	12	10
Broadband City / Broadband Metropolis	1 / 1	8 / 1	0 / 2
Wireless city / Mobile City	27 / 33	20 / 30	47 / 57
Ubiquitous city	61	16	59
Eco-city	264	215	494

Table 1: terms for phase 1 search and corresponding article results

The initial search was performed in late January 2014. A broad set of results was returned, where many journals -only in ElSevier an amount of 37 journals- appear to publish relative to smart city works. This initial finding is not surprising due to the broad smart city context. It is beyond the purposes of this chapter to illustrate how many articles per journal appeared. Moreover, for the purposes of this chapter, these results were limited to the ICT context, which resulted in a list of 32 journals from various publishers. This list contains the *Communications of the ACM; International Journal of Electronic Government Research; New Media & Technology; Public Administration Review; Cities; Pervasive and Mobile Computing; Journal of Urban Technology; Environment and Planning B; City; Environment and urbanization; Applied Geography; Information and Management; Electronic Commerce Research and Applications; Expert Systems with Applications; Sustainable Cities and Society; IEEE Internet Computing; Wireless Communications Journal; Behaviour and*

Information Technology; Journal of The Association For Information Science And Technology; Technological Forecasting & Social Change; Journal of Economic Literature; Future Generation Computer Systems; Automation in Construction; Environmental Modelling & Software; Applied Energy; Habitat International; Journal of e-Government; Government Information Quarterly; Electronic Government, An International Journal (EGAIJ); International Journal of Electronic Government Research; Information Polity; Electronic Journal of e-Government; Transforming Government: Process, People and Policy; and Journal of Information Technology and Politics. All were located to have hosted several articles regarding smart city dated from 1998.

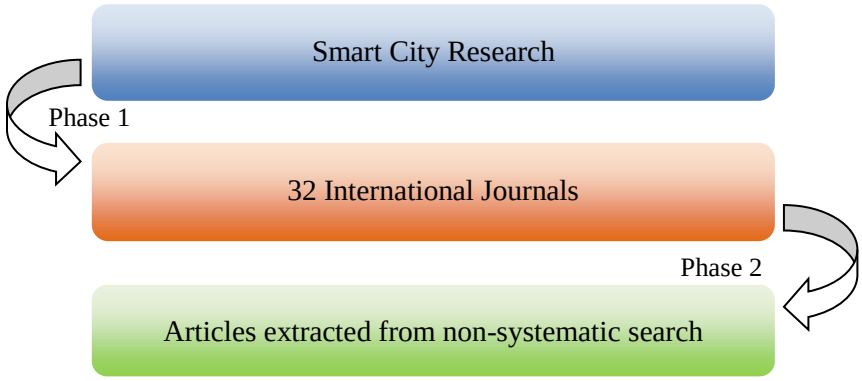

Figure 1: search method

The above systematic search in journals was complemented by an analysis of secondary sources (Phase 2), including articles referenced by papers identified in Phase 1, as well as articles from non-systematic searching (especially in conference proceedings and books), research projects' reports, PhD theses and business products (Figure 1). To this end, International Conferences that have been organized by IEEE –i.e., the Hawaii International Conference on System Sciences (HICSS), Info-tech and Info-day and PICMET-; Digital Government Society (dg.o); DEXA; United Nations University (ICEGOV); Association for Information Systems (AMCIS); and IARIA also demonstrate relevant work. Various scientific books that have been published by publishers such as Springer and Routledge host as technological aspects, social issues, financial and managerial perspectives of the smart city etc. Finally, postgraduate dissertations and PhD theses have been developed in the smart

city domain and they return useful findings with regard to smart city and Urban Development (Lee & Oh, 2008; Wang & Wu; 2001).

c) Search Strategy: As for the articles published in the above mentioned list of journals, their title, abstract and keywords were scanned for smart city classification terms (Table 1). From the resulting set of articles, duplicates and papers irrelevant to this study were excluded manually (screening). This applies to papers irrelevant to the ICT, for instance, on "urbanism" returning from the crawl of the search term "city"; "houses" that came up from "smart city"; and to "smart city-regionalism" that was triggered by "smart city". Moreover, due to the size of the returned results, emphasis was given on a set of the most recent articles (dated between 2011 and 2014), as well as on corresponding review articles, which have already analyzed extensive literature parts. A comparison was performed on these review articles, with regard to the perspectives (or domains) they use to analyze smart city and a common framework is summarized.

Investigated Journals	Results from crawling "smart city"	Dated after 2011	Number of articles after screening	Results (complete list)
Technological Forecasting & Social Change	134	50	5	Bulu, M. (2013); Lee et al. (2013); Lee et al. (2013) (b); Marletto (2014); Paroutis et al. (2013)
Cities	305	170	3	Neirotti et al. (2014); Debnath et al. (2014); Desouza, & Flanery (2013)
Journal of Urban Technology	96	35	3	Allwinkle & Cruickshank (2011); Caragliou et al. (2011); Kuk & Janssen (2011)
The Journal of Systems and Software	50	23	1	Piro et al. (2014)
Journal of the Association for Information Science and Technology	43	18	1	Stock (2011)

Table 2: smart city in research journals (1998–2014)

As a result, 41 publications related to the smart-city domain were selected and analyzed in this chapter, 24 of which were extracted from corresponding journals (Table 2). Most

of these papers, five in each, were identified in Technological Forecasting & Social Change, while Cities and Journal of Urban Technology follow with three articles. Journal of Urban Technology alone, has published several works in smart city domain (96 results come out from the keywords "smart city"), but only three have been included in this chapter's analysis according to their relevance and date.

The smart city was introduced in the Australian cases of Brisbane and Blacksbourg (Anthopoulos & Vakali, 2012) where the ICT supported the social participation and the community's cohesion with the narrowness of the digital divide, together with the availability of public information and services. The smart city was later evolved to (a) an urban space for business opportunities, which was followed by the network of Malta, Dubai and Kochi (www.smartcity.ae); and to (b) ubiquitous technologies installed across the city, which are integrated into everyday objects and activities.

Moreover, smart city has been approached as part of the broader term of digital city by (Anthopoulos & Tsoukalas, 2006), where a generic multi-tier common architecture for digital cities was introduced, and assigned smart city to the software and services layer of this architecture. For the purposes of this article, the term smart city will refer to all alternative approaches to metropolitan ICT cases. In the following paragraphs an analysis over various important smart cities is presented, outlining their mission, their business case and their organizational structure.

Anthopoulos & Fitsilis (2013) performed an extensive review on smart city technological evolution and resulted in a corresponding classification with regard to the ICT that is installed in urban agglomerations. Churabi et al. (2012) investigated smart city definition and concluded on an integrative framework for smart city analysis. Neirotti et al. (2014) provide a recent corresponding literature review and they define two classification domains for smart city theory with regard to the exploitation of tangible and intangible urban assets: Hard domain, which concern energy, lighting, environment, transportation, buildings, and healthcare and safety issues. Soft domain, which address education, society, government and economy. From their domain analysis, they conclude on six application domains for smart city, which address corresponding challenges: natural resources and energy; transport and mobility; buildings; living; government; and economy and people. This six-domain model comes in contrast to the six main challenges to managing an urban community: providing an economic base; building efficient urban

infrastructure; improving the quality of life and place; ensuring social integration; conserving natural environmental qualities, and; guaranteeing good governance (Yigitcanlar & Lee, 2013). Additionally, an analysis over a set of European research projects (Piro et al., 2014) addresses smart growth nine areas: transportation; government; safety; society; health-care; education; buildings and urban planning; environment; energy and water. Furthermore, Desouza & Flanery (2013) perform a smart city classification with regard to their resilience and they identified 7 domains (components and interaction), which concern resources; physical; people; institutions; processes; activities; and social. Moreover than not, Lee et al. (2013) introduce their framework for smart-city analysis, which is rather economic-oriented and consists of 7 dimensions: urban openness; service innovation; parnerships formation; urban proactiveness; infrastructure integration; and governance. New urbanism on the other hand (Wey & Hsu, 2014), introduces a 9 principles' model, most of which align to the above-mentioned application domains, while it does not focus on government issues. This comparison seems to extend Giffinger et al. (2007) urban smartness "footprint" measurement model, with the incorporation of two more domains: urban infrastructure; and social coherency (Table 3).

[Table 3 about here]

However, an in-depth analysis of the articles in this study extends the above review and provides evidence of the following arguments and key areas of study:

a) Smart city: a wide range of articles were identified to present various ICT approaches to urban challenges. These challenges vary from measuring and increasing urban capacity for smartness (smartness "footprint") (Giffinger et al., 2007; Akçura & Avci, 2013; Lee et al., 2013); everyday life's improvement (Piro et al., 2014); energy consumption (Kramers et al., 2014; Lazaroiu and Roscia, 2012; Kim et al., 2012; Yamagata & Seya, 2013); urban and building architectural facts (Rassia and Pandalos, 2014; Vollaro et al., 2014). Moreover, 19 research projects, which were funded by the European Union (EU) (Piro et al., 2014), are focused on Internet-of-Things (IoT), the corresponding architectures and smart city services, while they are aligned to nine application domains.

b) Smart growth: with regard to sprawl management and resilience (Desouza & Flanery, 2013; Wey & Hsu, 2014); hard asset management such as transportation (Marletto, 2014; Debnath et al., 2014), even with big data utilization (Dobre & Xhafa, 2013); to smart communities' and urban innovation networks' development, which account a city's within regional and national urban systems (Malecki, 2013; Lee et al., 2013 (b)); sustainable development and eco-living (Yigitcanlar & Lee, 2013; Yamagata & Seya, 2013); or even city efficiency's and effectiveness's increase (Bulu, 2013).

c) Living labs: they concern areas for large scale testing beds (Cosgrave et al., 2013) as well as flourish landscapes for citizen-sourced innovation (Komninos, 2002; Pallot et al., 2011); citizens as sensors is a novel approach that is applied for bottom-up information collection from the urban space (Arribas-Bel, 2013; Sanchez et al., 2011);

d) Creative industry: it concerns ICT utilization for entrepreneurship in creative market (Anthopoulos & Fitsilis, 2013); the niche smart city market, which varies from "smart city in a box" products (Paroutis et al., 2013; Alcatel-Lucent, 2012) as well as cities from scratch (Lindsay, 2010).

3. Discussion

The number of the located research journals (32) and their context's differentiation – varying from construction, energy, social sciences, transportation, urbanship, ICT etc.- that present corresponding to smart city works illustrate the attention, which the scientific community pays on this domain. The term is confirmed to be ambiquous, although the perspectives (application domains) that scholars use to approach smart city can be considered to be common.

The outcomes from the analysis of these articles illustrate that despite identifying 24 exceptional articles, which are clearly oriented to smart city, their corresponding scholars approach the term with four key-areas (schools of thought): smart city; smart growth; living labs; and creative industry. Representatives from these schools approach the smart city from corresponding perspectives and utilize the intelligent urban space with means that address particular problems (i.e., creative industry considers city's capacity for innovative or media production).

Moreover, a conceptual framework for approaching a smart city appears to be structured and consists of the following application domains:

- *Resource (utilization and management)*: it deals with natural resources, energy, water monitoring and management;
- *Transportation*: it concerns ICT utilization for transportation management, as well as intelligent transportation products and mobility in general;
- *Urban infrastructure*: refers to building, agglomeration and sprawl management with the ICT;
- *Living*: covers education, health, safety and quality of life in urban space;
- *Government*: mentions public e-service delivery; e-democracy and participation; accountability and transparency; and administration's efficiency within the city;
- *Economy*: covers areas that reflect domestic product in city; innovative spirit; employment; and e-business;
- *Coherency*: deals with social issues that address digital divide; social relations; and ICT connectivity.

Country	Institutes	Scholars
Greece	2 Universities 1 Research center	5
Italy	5 Universities	13
Japan	1 University 1 Insitute	3
Mexico	1 public organization	1
Netherlands	1 Enterprise	1
Romania	1 University	2
Singapore	1 University 1 Institute	5
South Korea	5 Universities 1 research consortium 2 enterprises	5
Spain	1 University	1
Sweden	2 Universities 1 enterprise	4
Switzerland	1 University	2
Taiwan	2 Universities	3
Turkey	2 Universities	3
United Arab Emirates	1 enterprise	1
U.K.	2 Universities	2
U.S.A.	16 Universities 4 enterprises 3 public organizations	18

Table 4: an indicative picture of the involved academia and industry around the world.

Beyond the above analyzed journal articles, a set of 17 publications were analyzed under phase 2 and contribute with useful findings this chapter. An important outcome concerns the involvement of the three of the construction, the ICT and the electronics industries in this niche smart-city market, which is affected by globalization. Major representatives from these three industries appear (i.e., Gale and HGC; CISCO and Alcatel; and Hitachi accordingly) to play important role in this market's formulation and they are mainly grounded in the United States and in the emerging Asian market.

Another useful finding concerns the identification of an indicative representative picture with regard to the most recently active countries, their involved stakeholders (universities, research centers, enterprises etc.) and scholars (Table 4). From the investigated articles it appears that although smart cities are spread around the globe, this domain mainly interests South Korea, southern Europe Countries and the U.S.A.

All the above findings can be used to answer this paper's research question. More specifically, with regard to the fundamental theories, four key areas appear to attract smart-city research: ICT in urban space (smart-city); smart growth; living labs; and creative industry. Their corresponding concepts illustrate almost all urban challenges and how they can be addressed by the ICT. Furthermore, all recent ICT trends were found in the corresponding literature analysis: Internet-of-Things; Big Data; Open data and e-Government; and Smart Grids are only some of these trends. Moreover, eight (8) different models have been introduced for smart city analysis, which can all align to a common conceptual framework consisting of eight (8) perspectives (application domains).

4. Conclusions

Smart city is a "booming" phenomenon, which is still ambiguous in literature. Many different sciences look into the smart city domain and this can be met both in the academia (from the involved journals, schools and scholars) and the industry. Almost all sciences can be met in the smart city domain, which approach this phenomenon from different perspectives. Scholars and schools across the world are being or have been investigated this phenomenon and an indicative "picture" is provided. On the other hand,

three alternative industries appear to meet in this domain and create an emerging corresponding market: the ICT; the construction; and the electronics.

In order to answer this chapter's question, a holistic literature review was performed, with a method that was inspired by Niehaves (2011). In this respect and with regard to the initially grounded research question, a smart city was viewed with four disciplinary perspectives, which were documented to form the corresponding smart city fundamental theories: ICT; urban planning and growth; living labs as large-scale testing beds; eco or green city and corresponding ecological aspects; and creative industry in a city. All the above scientific areas appear to "meet" in smart city and various outcomes are generated. Moreover, corresponding concepts illustrate almost all urban challenges and how they can be addressed by the ICT. Furthermore, all recent ICT trends were found in the corresponding literature analysis: Internet-of-Things; Big Data; Open data and e-Government; and Smart Grids are only some of these trends. Finally, eight (8) different models have been introduced for smart city analysis, which can all align to a common conceptual framework consisting of eight (8) perspectives (application domains). This conceptual framework is introduced in this chapter, which can be utilized in further smart city exploitation. Although this framework is based on existing literature findings, it would useful to be tested and validated either by experts or under a real case study.

Finally, some limitations have to be considered, which address future research: although a quite effective sample of research journal articles were investigated, many were not included in this review either because they were citations in the investigated publications, or they did not meet the criteria of this study. To this end, smart city studies older than 2011 are also important to this domain and they concern a roadmap to today's smart city (Anthopoulos & Fitsilis, 2013). Moreover, other industries are also involved in smart city domain but they were not accounted in this study, since they did not meet directly the ICT context (i.e., biomedicine, economics, smart materials etc.). However, it is estimated by the author that a unique literature review is extremely complex to be performed with regard to the smart city. On the contrary, detailed reviews will be more effective if they address the alternative perspectives of the introduced conceptual framework or the identified key areas.

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Domain	Neirotti et al. (2014)	Piro et al. (2014)	Desouza & Flanery (2013)	Wey & Hsu (2014)	Lee et al. (2013)	Yigitcanlar & Lee (2013)	Churabi et al. (2012)	Giffinger et al. (2007)
Resource	Natural resources and energy	Environment, energy and water	Resources	Sustainability	Urban proactiveness	Environment	Natural environment	Smart Environment
Transportation	transport and mobility	Transportation	Activities	Walkability, Green Transportation				Smart Mobility
Urban infrastructure	Buildings	Buildings and urban planning	Physical	Quality Architecture & Urban Design , Mixed Housing, Traditional Neighborhood Structure	Infrastructure integration	Urban infrastructure	Built infrastructure	
Living	Living	Health-care, Safety, Education	People	Increased Density	Quality of Life	Quality of life and place	Technology	Smart Living
Government	Government	Government	Processes		Governance	Good governance	Policy, Governance	Smart Government
Economy	Economy and people		Institutions	Mixed-Use & Diversity	Urban openness, Partnerships Formation, Service Innovation,	Economic base	Economy	Smart Economy
Coherency		Society	Social	Connectivity		Social integration	People & communities	

Table 3: smart-city conceptual framework