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Smart Cities: Definitions, Dimensions, Performance, and Initiatives

Vito Albino, Umberto Berardi and Rosa Maria Dangelico

ABSTRACT *As the term "smart city" gains wider and wider currency, there is still confusion about what a smart city is, especially since several similar terms are often used interchangeably. This paper aims to clarify the meaning of the word "smart" in the context of cities through an approach based on an in-depth literature review of relevant studies as well as official documents of international institutions. It also identifies the main dimensions and elements characterizing a smart city. The different metrics of urban smartness are reviewed to show the need for a shared definition of what constitutes a smart city, what are its features, and how it performs in comparison to traditional cities. Furthermore, performance measures and initiatives in a few smart cities are identified.*

KEYWORDS *smart city*; *indicators*; *sustainability*; *urban development*

Introduction

In the last two decades, the concept of "smart city" has become more and more popular in scientific literature and international policies. To understand this concept it is important to recognize why cities are considered key elements for the future. Cities play a prime role in social and economic aspects worldwide, and have a huge impact on the environment (Mori and Christodoulou, 2012). According to the United Nations Population Fund, 2008 marked the year when more than 50 percent of all people, 3.3 billion, lived in urban areas, a figure expected to rise to 70 percent by 2050 (UN, 2008). In Europe, 75 percent of the population already lives in urban areas and the number is expected to reach 80 percent by 2020. The importance of urban areas as a global phenomenon is confirmed by the diffusion of megacities of more than 20 million people in Asia, Latin America, and Africa (UN, 2008). As a result, nowadays most resources are consumed in cities worldwide, contributing to their economic importance, but also to their poor environmental performance. Cities consume between 60 percent and 80 percent of energy worldwide and are responsible for large shares of GHG emissions (UN, 2008). However, the lower the urban density, the more energy is consumed for electricity and transportation, as proved by the fact that CO_2 emissions per capita drop with the increase of urban areas density (Hammer et al., 2011).

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The metabolism of cities generally consists of the input of goods and the output of waste with consistent negative externalities, which amplify social and economic problems. Cities rely on too many external resources and, as a matter of fact, they are (and probably will always be) consumers of resources. Promoting sustainability has been interpreted through the promotion of natural capital stocks. Other, more recent, interpretations of urban sustainability have promoted a more anthropocentric approach, according to which cities should respond to people's needs through sustainable solutions for social and economic aspects (Turcu, 2013; Berardi, 2013a; 2013b).

The current scenario requires cities to find ways to manage new challenges. Cities worldwide have started to look for solutions which enable transportation linkages, mixed land uses, and high-quality urban services with long-term positive effects on the economy. For instance, high-quality and more efficient public transport that responds to economic needs and connects labor with employment is considered a key element for city growth. Many of the new approaches related to urban services have been based on harnessing technologies, including ICT, helping to create what some call "smart cities."

The concept of the smart city is far from being limited to the application of technologies to cities. In fact, the use of the term is proliferating in many sectors with no agreed upon definitions. This has led to confusion among urban policy makers, hoping to institute policies that will make their cities "smart."

This paper seeks to advance state-of-the-art knowledge on what a smart city is, what its key dimensions are, and how its performance can be evaluated. It is based on a review of the literature, including peer reviewed papers published after 2008. In particular, it is structured as follows. First, the main definitions of "smart city" are reviewed, highlighting the different meanings given to this concept and the several perspectives through which it has been studied; next, it analyzes the key dimensions of a smart city; then it focuses on the measures of performance of a smart city, reports on the experiences of so called, smart cities; finally closing with a discussion of the main findings of the study.

Definitions of Smart Cities

Many definitions of smart cities exist. A range of conceptual variants is often obtained by replacing "smart" with alternative adjectives, for example, "intelligent" or "digital". The label "smart city" is a fuzzy concept and is used in ways that are not always consistent. There is neither a single template of framing a smart city, nor a one-size-fits-all definition of it (O'Grady and O'Hare, 2012).

The term was first used in the 1990s. At that time, the focus was on the significance of new ICT with regard to modern infrastructures within cities. The California Institute for Smart Communities was among the first to focus on how communities could become smart and how a city could be designed to implement information technologies (Alawadhi et al., 2012). Some years later, the Center of Governance at the University of Ottawa started criticizing the idea of smart cities as being too technically oriented. In this reading, the smart city should have a strong governance-oriented approach which emphasizes the role of social capital and relations in urban development. However, the "smart city" label diffused in the first years of the new century as an "urban labelling" phenomenon. A few years ago, researchers started asking real smart cities to

stand up and to show the many aspects that are hidden behind a self-declaratory attribution of the label of "smart city" (Hollands, 2008).

Nam and Pardo (2011) investigated possible meanings of the term "smart" in the smart city context. In particular, in the marketing language, "smartness" is a more user-friendly term than the more elitist term "intelligent," which is generally limited to having a quick mind and being responsive to feedback. Other interpretations suggest that "smart" contains the term "intelligent," because the smartness is realized only when an intelligent system adapts itself to the users' needs.

Harrison et al. (2010), in an IBM corporate document, stated that the term "smart city" denotes an "instrumented, interconnected and intelligent city." "Instrumented" refers to the capability of capturing and integrating live real-world data through the use of sensors, meters, appliances, personal devices, and other similar sensors. "Interconnected" means the integration of these data into a computing platform that allows the communication of such information among the various city services. "Intelligent" refers to the inclusion of complex analytics, modelling, optimization, and visualization services to make better operational decisions (Harrison et al., 2010).

In the urban planning field, the term "smart city" is often treated as an ideological dimension according to which being smarter entails strategic directions. Governments and public agencies at all levels are embracing the notion of smartness to distinguish their policies and programs for targeting sustainable development, economic growth, better quality of life for their citizens, and creating happiness (Ballas, 2013).

Table 1 reports some of the different definitions and meanings given to the concept of "smart city." However, the table clarifies that the smart city concept is no longer limited to the diffusion of ICT, but it looks at people and community needs. Batty et al. (2012) clarified this aspect stressing that the diffusion of ICT in cities has to improve the way every subsystem operates, with the goal of enhancing the quality of life.

Nam and Pardo (2011) discussed the difference between the concept of the smart city and other related terms, such as digital, intelligent or ubiquitous city, along with the three categories of technology, people, and community. From the technology perspective, a smart city is a city with a great presence of ICT applied to critical infrastructure components and services (Washburn et al., 2010). ICT permeate into intelligent-acting products and services, artificial intelligence, and thinking machines (Klein and Kaefer, 2008). Smart homes and smart buildings are examples of systems equipped with a multitude of mobile terminals and embedded devices as well as connected sensors and actuators (Ghaffarian Hoseini et al., 2013). Hancke et al. (2013) provide an overview of the state of the art sensors used for monitoring physical infrastructure in a smart city and discuss a large number of pertained applications. For example, advanced energy sensing enables more accurate metering needed for the development of urban smart energy grids, whereas mobility sensors improve traffic control schemes. Worldwide research is currently focusing on the wireless sensor network node technology, system miniaturization, intelligent wireless technology, communication and heterogeneous network, network planning and deployment, comprehensive perception and information processing, code resolution service, searching, tracking, and information distribution to make a smart city the extension of a smart space to the entire city scale (Liu and Peng, 2013).

Table 1: Definitions of a smart city

Definition	Source
Smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality.	Bakıcı et al. (2012)
Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centers that are at once integrated, habitable, and sustainable.	Barrionuevo et al. (2012)
A city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.	Caragliu et al. (2011)
Smart cities will take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone.	Chen (2010)
Two main streams of research ideas: 1) smart cities should do everything related to governance and economy using new thinking paradigms and 2) smart cities are all about networks of sensors, smart devices, real-time data, and ICT integration in every aspect of human life.	Cretu (2012)
Smart community – a community which makes a conscious decision to aggressively deploy technology as a catalyst to solving its social and business needs – will undoubtedly focus on building its high-speed broadband infrastructures, but the real opportunity is in rebuilding and renewing a sense of place, and in the process a sense of civic pride. [. . .] Smart communities are not, at their core, exercises in the deployment and use of technology, but in the promotion of economic development, job growth, and an increased quality of life. In other words, technological propagation of smart communities isn't an end in itself, but only a means to reinventing cities for a new economy and society with clear and compelling community benefit.	Eger (2009)
A smart city is based on intelligent exchanges of information that flow between its many different subsystems. This flow of information is analyzed and translated into citizen and commercial services. The city will act on this information flow to make its wider ecosystem more resource-efficient and sustainable. The information exchange is based on a smart governance operating framework designed to make cities sustainable.	Gartner (2011)
A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens. Smart city generally refers to the search and identification of intelligent solutions which allow modern cities to enhance the quality of the services provided to citizens.	Giffinger et al. (2007)
A smart city, according to ICLEI, is a city that is prepared to provide conditions for a healthy and happy community under the challenging conditions that global, environmental, economic and social trends may bring.	Guan (2012)
A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens.	Hall (2000)
A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city.	Harrison et al. (2010)

(*Continued*)

Table 1: Continued

Definition	Source
(Smart) cities as territories with high capacity for learning and innovation, which is built-in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management.	Komninos (2011)
Smart cities are the result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such smart cities are based on a promising mix of human capital (e.g. skilled labor force), infrastructural capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities).	Kourtit and Nijkamp (2012)
Smart cities have high productivity as they have a relatively high share of highly educated people, knowledge-intensive jobs, output-oriented planning systems, creative activities and sustainability-oriented initiatives.	Kourtit et al. (2012)
Smart city [refers to] a local entity - a district, city, region or small country -which takes a holistic approach to employ[ing] information technologies with real-time analysis that encourages sustainable economic development.	IDA (2012)
A community of average technology size, interconnected and sustainable, comfortable, attractive and secure.	Lazaroiu and Roscia (2012)
The application of information and communications technology (ICT) with their effects on human capital/education, social and relational capital, and environmental issues is often indicated by the notion of smart city.	Lombardi et al. (2012)
A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains.	Nam and Pardo (2011)
Creative or smart city experiments [. . .] aimed at nurturing a creative economy through investment in quality of life which in turn attracts knowledge workers to live and work in smart cities. The nexus of competitive advantage has [. . .] shifted to those regions that can generate, retain, and attract the best talent.	Thite (2011)
Smart cities of the future will need sustainable urban development policies where all residents, including the poor, can live well and the attraction of the towns and cities is preserved. [. . .] Smart cities are cities that have a high quality of life; those that pursue sustainable economic development through investments in human and social capital, and traditional and modern communications infrastructure (transport and information communication technology); and manage natural resources through participatory policies. Smart cities should also be sustainable, converging economic, social, and environmental goals.	Thuzar (2011)
A smart city is understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth. These aspects lead to smart city conceptions as "green" referring to urban infrastructure for environment protection and reduction of CO_2 emission, "interconnected" related to revolution of broadband economy, "intelligent" declaring the capacity to produce added value information from the processing of city's real-time data from sensors and activators, whereas the terms "innovating", "knowledge" cities interchangeably refer to the city's ability to raise innovation based on knowledgeable and creative human capital.	Zygiaris (2013)

(*Continued*)

Table 1: Continued

Definition	Source
The use of Smart Computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient.	Washburn et al. (2010)
Smart Cities initiatives try to improve urban performance by using data, information and information technologies (IT) to provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration among different economic actors, and to encourage innovative business models in both the private and public sectors.	Marsal-Llacuna et al. (2014)

For corporations such as IBM, Cisco Systems, and Siemens AG, the technological component is the key component to their conceptions of smart cities. Their approach has recently been critiqued by authors such as Adam Greenfield who argues in *Against the Smart City* (2013) that corporate-designed cities such as Songdo (Korea), Masdar City (UAE), or PlanIT Valley (Portugal) eschew actual knowledge about how cities function and represent "empty" spaces that disregard the value of complexity, unplanned scenarios, and the mixed uses of urban spaces. There are authors, however, who have shown that technology could be used in cities to empower citizens by adapting those technologies to their needs rather than adapting their lives to technological exigencies (Cugurullo, 2013, Kitchin, 2014, Vanolo, 2014).

There are terms analogous to "smart cities" that add to the cacophony of terms relating to this phenomenon. As already stated, possible confusion related to the technology perspective of a smart city comes from the top-down and company-driven actions taken for creating a smart city. However, it also comes from the confusion with other similar terms, such as digital, intelligent, virtual, or ubiquitous city. These terms refer to more specific and less inclusive levels of a city, so that the concepts of smart cities often include them (Caragliu et al., 2011; Deakin and Al Waer, 2011; Townsend, 2013). For example a digital city refers to "a connected community that combines broadband communications infrastructure to meet the needs of governments, citizens, and businesses" (Ishida, 2002). The final goal of a digital city is to create an environment for information sharing, collaboration, interoperability, and seamless experiences anywhere in the city.

The notion of the "intelligent city" emerges at the crossing of the knowledge society with the digital city (Yovanof and Hazapis, 2009). According to Komninos et al. (2013), intelligent cities make conscious efforts to use information technology to transform life and work. The label intelligent implies the ability to support learning, technological development, and innovation in cities; in this sense, every digital city is not necessarily intelligent, but every intelligent city has digital components, although the "people" component is still not included in an intelligent city, as it is in a smart city (Woods, 2013). In a "virtual city," the city becomes a hybrid concept that consists of a reality, with its physical entities and real inhabitants, and a parallel virtual city of counterparts, a cyberspace. A "ubiquitous city" is an extension of the digital city concept in terms of wide accessibility. It makes the ubiquitous computing available to the urban elements everywhere (Greenfield, 2006; Townsend, 2013). Its characteristic is the creation of an

environment where any citizen can get any service anywhere and anytime through any device. The ubiquitous city is different from the virtual city because, while the virtual city reproduces urban elements by visualizing them within virtual space, the ubiquitous city is created by the inclusion of computer chips or sensors in urban elements (Lee et al., 2013).

As stated previously, the component that is missing in previous terms is that of people. These are the protagonists of a smart city, who shape it through continuous interactions. For this reason, other terms have often been associated with the concept of the smart city. For example, creativity is recognized as a key driver of smart city, and thus education, learning, and knowledge have central roles in a smart city (Thuzar, 2011). The notion of a smart city includes creating a climate suitable for an emerging creative class (Florida, 2002, 2005). The social infrastructure, such as intellectual and social capital, is an indispensable endowment to smart cities as it allows "connecting people and creating relationships" (Alawadhi et al., 2012). Smart people generate and benefit from the social capital of a city, so the smart city concept acquires the meaning of a mix of education/training, culture/arts, and business/commerce with hybrid social, cultural, and economic enterprises (Winters, 2011).

Focusing on education, Winters (2011) clarifies that a smart city is a center of higher education, better-educated individuals, and skilled workforces. Smart cities act as magnets for creative people and workers, and this allows the creation of a virtuous circle making them smarter and smarter. Consequently, a smart city has multiple opportunities to exploit its human potential and promote a creative life (Partridge, 2004). Glaeser and Berry (2006) showed that the most rapid urban growth rates have been achieved in cities where a high share of the educated labor force is available. The buzz concept of being clever, smart, skillful, creative, networked, connected, and competitive becomes a key ingredient of knowledge-based urban development (Dirks et al., 2010).

The term "knowledge city" has emerged from discussions about smart cities. It is a city that encourages the nurturing of knowledge (Edvinsson, 2006, Baqir and Kathawala, 2008, Yigitcanlar et al., 2008). There has been an explosion of literature about this term in the last several years. The development of a knowledge-based urban environments has recently been spurred by the advancement of new cloud technologies used for urban monitoring systems. In fact, as sensors collect terabytes of information, data need to be aggregated and processed (Hancke et al., 2013). Mitton et al. (2012) describe the potential of integrating cloud and sensors in smart cities and present a new architecture that provides the capability of obtaining any type of data acquired from different sensing infrastructures. In some cases, these technologies subvert the top-down, corporate vision some offer as a smart city. Instead, the large-scale diffusion of new sensors in devices such as smartphones allows individuals to share data collectively and extract information instantly.

Another category used by Nam and Pardo (2011) for clarifying the concept of the smart city is that of community. This perspective starts from the previous bottom-up knowledge scheme, and it aims at inspiring the sense of community among citizens. The importance of this factor emulates the concept of smart communities where members and institutions work in partnership to transform their environment (Berardi, 2013a, 2013b). This means that the community of a smart city needs to feel the desire to participate and promote a (smart) growth. The concept of smart growth was largely used in the 1990s within the framework of New Urbanism, as a community-driven reaction to worsening trends in traffic

congestion, school overcrowding, air pollution, loss of open space, effacement of valued historic places, and skyrocketing public facility costs (Eger, 2009). These goals are still among the reasons smart cities are attractive.

Perhaps a reason that there is no general agreement about the term "smart cities" is that the term has been applied to two different kinds of "domains." It has, on the one hand, been applied to "hard" domains such as, buildings, energy grids, natural resources, water management, waste management, mobility, and logistics (Neirotti et al, 2014), where ICT can play a decisive role in the functions of the systems. On the other hand, the term has also been applied to "soft domains" such as, education, culture, policy innovations, social inclusion, and government, where the application of ICT are not usually decisive.

Dimensions of a Smart City

Dirks and Keeling (2009) stress the importance of the organic integration of a city's various systems (transportation, energy, education, health care, buildings, physical infrastructure, food, water, and public safety) in creating a smart city. Researchers who support this integrated view of a smart city often underline that in a dense environment, like that of cities, no system operates in isolation. Kanter and Litow (2009) stress this aspect in their *Manifesto for Smarter Cities*, where they affirm that infusing intelligence into each subsystem of a city, one by one, is insufficient to create a smart city, as this should be treated as an organic whole. However, many researchers, with the intent of clarifying what constitutes a smart city have separated this concept into many features and dimensions, justifying this decision with the complexity of managing the smart city concept in a holistic way.

Komninos (2002, 2011) in his attempt to delineate the features of an intelligent city, indicated that this has four possible dimensions (*attention should be paid to the less inclusive reference to "intelligent" instead of "smart" city*). The first dimension concerns the application of a wide range of electronic and digital technologies to create a cyber, digital, wired, informational or knowledge-based city; the second is the use of information technology to transform life and work; the third is to embed ICT in the city infrastructure; the fourth is to bring ICT and people together to enhance innovation, learning, and knowledge.

Giffinger et al. (2007) identified four components of a smart city: industry, education, participation, and technical infrastructure. This list has since been expanded in a recent project conducted by the Centre of Regional Science at the Vienna University of Technology which has identified six main components (Giffinger and Gudrun, 2010). These components are a smart economy, smart mobility, a smart environment, smart people, smart living, and smart governance. These writers rely on the traditional and neoclassical theories of urban growth and development: regional competitiveness, transport and ICT economics, natural resources, human and social capital, quality of life, and participation of society members. Particularly interesting in the previous list of components of a smart city is the inclusion of the "quality of life." This component emphasizes the definition of a smart city as a city that increases the life quality of its citizens (Giffinger et al., 2007). However, many researchers argue that quality of life may not represent a separate dimension of a smart city, as all the actions taken in the other areas should have the objective of raising the quality of life, so that this represents the basic component (Shapiro, 2006).

Table 2: Components of a smart city and related aspects (adapted from Lombardi et al., 2012)

Components of a smart city	Related aspect of urban life
smart economy	Industry
smart people	education
smart governance	e-democracy
smart mobility	logistics & infrastructures
smart environment	efficiency & sustainability
smart living	security & quality

Lombardi et al. (2012) have associated the six components with different aspects of urban life, as shown in Table 2. The smart economy has been associated with the presence of industries in the field of ICT or employing ICT in production processes. Smart mobility refers to the use of ICT in modern transport technologies to improve urban traffic. Aspects referring to the preservation of the natural environment in cities are extensively covered in Giffinger et al. (2007), and Albino and Dangelico (2012).

According to Nam and Pardo (2011), the key components of a smart city are the technology, the people (creativity, diversity, and education), and the institutions (governance and policy). Connections exist between these last two components, so that a city is really smart when investments in human and social capital, together with ICT infrastructures, fuel sustainable growth and enhance the quality of life. Although the point of view of this paper is to go beyond the simple identification of a smart city with the dense presence of ICT, these are surely a key element as they transform life and work. A smart city surely provides some sort of interoperable and Internet-based government services that enable ubiquitous connectivity and transform key government processes towards citizens and businesses (Al-Hader et al., 2009). However, smart cities must integrate technologies, systems, services, and capabilities into an organic network that is sufficiently multi-sectorial and flexible for future developments, and moreover, open-access. This means that ICT must be a facilitator for creating a new type of communicative environment, which requires the comprehensive and balanced development of creative skills, innovation-oriented institutions, broadband networks, and virtual collaborative spaces (Komninos, 2011). Paskaleva (2011) extensively discussed the topics of open innovation, and user engagement, and the risk that a strong corporate-based approach to creating smart cities may pose risks for the independence of governments.

Smarter cities start from the human capital side, rather than blindly believing that ICT can automatically create a smart city (Shapiro, 2006, Holland, 2008). Approaches towards education and leadership in a smart city should offer environments for an entrepreneurship accessible to all citizens. The smart governance instead of being elective, needs ridding of barriers related to language, culture, education, and disabilities. The smart people factor comprises various aspects, like affinity to lifelong learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism, open-mindedness, and participation in public life (Nam and Pardo, 2011). Also problems associated with urban agglomerations can be solved by creativity, human capital, and cooperation among relevant stakeholders (Baron, 2012). Therefore, the label "smart city" should refer to the capacity of clever people to generate clever solutions to urban problems.

Smart governance means various stakeholders are engaged in decision making and public services. ICT-mediated governance, also called e-governance, is fundamental in bringing smart city initiatives to citizens, and to keeping the decision and implementation process transparent. However, the spirit of e-governance in a smart city should be citizen-centric and citizen-driven. Table 3

Table 3: Key dimensions of a smart city

Key dimensions of a smart city	Source
IT education IT infrastructure IT economy quality of life	Mahizhnan (1999)
economy mobility environment people governance	Giffinger et al. (2007)
technology economic development job growth increased quality of life	Eger (2009)
quality of life sustainable economic development management of natural resources through participatory policies convergence of economic, social, and environmental goals	Thuzar (2011)
economic socio-political issues of the city economic-technical-social issues of the environment interconnection instrumentation integration applications innovations	Nam and Pardo (2011)
economic (GDP, sector strength, international transactions, foreign investment) human (talent, innovation, creativity, education) social (traditions, habits, religions, families) environmental (energy policies, waste and water management, landscape) institutional (civic engagement, administrative authority, elections)	Barrionuevo et al. (2012)
human capital (e.g. skilled labor force) infrastructural capital (e.g. high-tech communication facilities) social capital (e.g. intense and open network linkages) entrepreneurial capital (e.g. creative and risk-taking business activities)	Kourtit and Nijkamp (2012)
management and organizations technology governance policy context people and communities economy built infrastructure natural environment	Chourabi et al. (2102)

outlines the dimensions of "smart city" as advanced by various scholars of the phenomenon.

The most common characteristics of smart cities emerging from this table are:

- a city's networked infrastructure that enables political efficiency and social and cultural development
- an emphasis on business-led urban development and creative activities for the promotion of urban growth
- social inclusion of various urban residents and social capital in urban development
- the natural environment as a strategic component for the future.

Measures of Performance

Different methods and measurement indices have been developed so far according to the several meanings of the concept of smart city reviewed in previous sections. Rating systems through synthetic quantitative indicators are receiving increasing attention among city managers and policy makers to decide where to focus time and resources, as well as to communicate city performance to citizens, visitors, and investors (Berardi, 2013a, 2013b). One of the values of these systems is the capacity to represent a metric of comparison, which overcomes self-proclamations of being a smart city. This section aims to report, through a description of existing rating systems, the indicators that are currently used to assess smart city initiatives. Moreover, at the end of this section some notes about the use of these systems for city rankings is reported.

The University of Vienna developed an assessment metric to rank 70 European medium-sized cities (Giffinger et al., 2007). This metric uses specific indicators for each of the six identified dimensions of a smart city (See Table 3). For example, smart mobility is divided into local accessibility, international accessibility, availability of ICT-infrastructure, and sustainable and safe transport systems. Another assessment system has been developed by the Intelligent Community Forum, which annually announces cities awarded as Smart 21 Communities. This metric is based on five factors: broadband connectivity, a knowledgeable workforce, digital inclusion, innovation, and marketing and advocacy. More recently, Zygiaris (2013) developed a measurement system, identifying six layers of a smart city: the *city layer*, emphasizing that smart city notions must be grounded into the context of a city; *the green city layer*, inspired by new urbanization theories of urban environmental sustainability; *the interconnection layer*, corresponding to the city-wide diffusion of green economies; *the instrumentation layer*, emphasizing that smart cities require real-time system responses made by smart meters and infrastructure sensors; *the open integration layer*, highlighting that smart cities applications should be able to communicate, and share data, content, services, and information; *the application layer*, useful for smart cities to mirror real-time city operations into new levels of intelligently responsive operation; and *the innovation layer*, emphasizing that smart cities create a fertile innovation environment for new business opportunities.

A methodology to assess "the smart city index" has recently been proposed by Lazaroiu and Roscia (2012). The index helped the distribution of European funds in the 2020 strategic plan. The indicators which contributed to this index are not homogeneous and require a large amount of information. The problem of information availability and the difficulty in assigning weights for summing

together the considered indicators are among the limits of this method. The proposed approach uses a fuzzy procedure that allows defining a set of weights for combining the different indicators according to their relative importance.

A more sophisticated system to measure the smartness of a city has been proposed by Lombardi et al. (2012). These authors used a modified version of the triple helix model, a reference framework for the analysis of knowledge-based innovation systems that relates the three main agencies of knowledge creation: universities, industry, and government (Leydesdorff and Deakin, 2011). The authors added a new agent of knowledge creation to the previous three, the civil society, determining a four helices model. For each of the four drivers of innovation, they propose indicators of a smart city according to five clusters (Lombardi et al., 2012). This framework of analysis is composed of 60 indicators selected after a literature review which included EU project reports, the Urban Audit dataset, statistics of the European Commission, the European Green City Index, TISSUE, Trends and Indicators for Monitoring the EU Thematic Strategy on Sustainable Development of Urban Environment, and the smart cities ranking of European medium-sized cities. Surprisingly, they excluded the smart mobility dimension (Lombardi et al., 2012). Table 4 reports the complete list of indicators proposed by Lombardi et al. (2012) and Lazaroiu and Roscia (2012).

Carli et al. (2013) have recently proposed a framework to analyze and compare measurement systems for smart cities. They suggest dividing the measurement indicators into two categories: objective and subjective, and to con-

Table 4: List of indicators for smart cities assessment in some rating systems.

Source	No. indicators	Indicators of a smart city
Lombardi et al. (2012)	60	*smart economy*: Public expenditure on R&D, Public expenditure on education, GDP per head of city population, Unemployment rate, ... *smart people*: Percentage of population with secondary-level education, Foreign language skills, Participation in life-long learning, Individual level of computer skills, Patent applications per inhabitant, ... *smart governance*: Number of universities and research centers in the city, e-Government on-line availability, Percentage of households with Internet access at home, e-Government use by individuals, ... *smart environment*: ambitiousness of CO_2 emission reduction strategy, Efficient use of electricity, Efficient use of water, Area in green space, Greenhouse gas emission intensity of energy consumption, Policies to contain urban sprawl, Proportion of recycled waste, ... *smart living*: Proportion of the area for recreational sports and leisure use, Number of public libraries, Total book loans and other media, Museum visits, Theater and cinema attendance
Lazaroiu and Roscia (2012)	18	Pollution, Innovative spirits, CO_2, Transparent governance, Sustainable resource management, Education facilities, Health conditions, Sustainable, innovative and safe public transportation, Pedestrian areas, Cycle lanes, Green areas, Production of solid municipal waste, GWh household, Fuels, Political strategies and perspectives, Availability of ICT infrastructure, Flexibility of labor market

sider both physical infrastructures and context data together with citizens' satisfaction and perception of well-being. These authors also focused on the way in which indicators are measured, and revealed that together with traditional tools, new indicators for well-being are increasingly assessed through real-time data sensing, such as social network messages.

Many rankings are currently used to determine the smartness of cities in terms of comparisons of practices with other cities. The Global Power City Index was created by the Japanese Institute for Urban Strategies, and it is based on a collection of observed data, complemented with information on the perception of various stakeholders. This index maps out the strengths and weaknesses of cities and ranks them in a broadly composed comparative analysis, according to their comprehensive socioeconomic potential to attract creative people and excellent companies. As stated previously, the University of Vienna has ranked 70 middle-sized cities according to the metrics defined in Giffinger et al. (2007). Meanwhile, in the Unites States, the Natural Resources Defense Council has developed the Smarter Cities Ranking, which is characterized by a strong bias toward environmental-related criteria (IDA, 2012). Forbes, with the support of the scientist Joel Kotkin, published a list of the world's Smartest Cities. This ranking considers a city that is compact and efficient and provides favorable economic conditions. Considering that this ranking encourages a city to be an economic hub, an international trade and global city, it is not surprising that Singapore was considered the smartest city in this ranking (IDA, 2012). Urban ranking such as the IBM Smart City or the McKinsey Global Institute rankings periodically compare and classify urban areas (Arribas-Bel et al., 2013). Previous ranks help show good practices and may serve as an instrument for enhancing territorial capital and defining urban policies.

Experiences of Smart Cities

At the beginning of 2013, there were approximately 143 ongoing or completed self-designated smart city projects (Lee at al., 2014). Among these initiatives, North America had 35 projects; Europe, 47; Asia 50; South America 10; and the Middle East and Africa 10 (Lee at al., 2014). In Canada, Ottawa's "Smart Capital" project involves enhancing business, local government, and community through the use of Internet resources. Quebec City was a city highly dependent upon its provincial government because of its weak industry until the early 1990s, when the city government kicked off a public-private partnership to support a growing multimedia sector and high-tech entrepreneurship. In the United States, Riverside, California has been improving traffic flow and replacing aging water, sewer and electric infrastructure through a tech-based transformation. In San Diego and San Francisco, ICT have been major factors in allowing these cities to claim to be a "City of the Future" for the last 15 years (Lee et al., 2014).

The European Union has put in place smart city actions in several cities, including in Barcelona, Amsterdam, Berlin, Manchester, Edinburgh, and Bath. In the United Kingdom, almost 15 years ago, Southampton claimed to be the country's first smart city after the development of its multi-application smartcard for public transportation, recreation, and leisure-related transactions. Similarly, Tallinn has developed a large-scale digital skills training program, extensive e-government, and an award-winning smart ID card. This city is the center of economic development for all of Estonia, harnessing ICT by fostering high-tech

parks. The European Commission has introduced smart cities in line 5 of the Seventh Framework Program for Research and Technological Development. This program provides financial support to facilitate the implementation of a Strategic Energy Technology plan (SET-Plan) through schemes related to "Smart cities and communities" (Vanolo, 2014).

According to the statistics of the Chinese Smart Cities Forum, six provinces and 51 cities have included Smart Cities in their government work reports in China; of these, 36 are under new concentrated construction (Liu and Peng, 2013). Chinese smart cities are distributed densely over the Pearl and Yangtze River Deltas, Bohai Rim, and the Midwest area. Moreover, smart cities initiatives spread in all first-tier cities such as Beijing, Shanghai, and Shenzhen. The general approach followed in this city is to introduce some ICT during the construction of new infrastructure, with some attention to environmental issues but limited attention to social aspects.

Cugurullo (2013) has extensively described the genesis of Masdar City, one of the most well-known examples of new cities built according to the eco-city paradigm. Although this city was planned around the concept of sustainable development, it promised to be strongly grounded in economic concerns. Several people looked at this as an example of a free-economic high-tech market in an area connecting Asia and Europe. Economic crises have slowed this initiative, which was highly criticized for its corporate-pushed approach. Social requests and dreams of the local populations are hidden behind formal designs of the city, which unfortunately seems unable to overcome the limits of new planned cities.

Several Southeast Asian cities such as Singapore, Taiwan, and Hong Kong are following a similar approach, promoting economic growth through smart city programs. Singapore's IT2000 plan was designed to create an "intelligent island," with information technology transforming work, life, and play. More recently, Singapore has extensively been dedicated to implement its Master Plan iN 2015 and has already completed the Wireless@SG goal of providing free mobile Internet access anywhere in the city (IDA, 2012). Taoyuan in Taiwan is supporting its economy to improve the quality of living through a series of government projects such as E-Taoyuan and U-Taoyuan for creating e-governance and ubiquitous possibilities.

Another country that is trying extensively to implement smart city projects is Korea (Yigitcanlar and Lee, 2014). The largest smart city initiative in Korea is Songdo, a new town built from the ground in the last decade and which plans to house 75,000 inhabitants with an original estimated cost of $35 billion (already halved at the time of this writing). The plan includes installing a tele-presence in every apartment in order to create an urban space in which every resident can transmit information using various devices, whereas a city central brain should manage the huge amount of information (Shwayri, 2013, Halpern et al., 2013). At present, there are 13 projects in progress towards the smart city initiatives of New Songdo. This project suffers all the contradictions indicated in Masdar, and it is not surprising that some people criticize these examples as real estate initiatives, where the "smart" label is included as a consequence of the simple adoption of some modern ICT. Surely, these cities show a strong link to neoliberal urban development policies where the construction of a smart city image becomes useful to attract investments, leading sector professionals, and workers (Vanolo, 2014).

In order to show some multi-sectorial initiatives promoted within strategies for smart cities, Table 5 reports the different projects promoted by three cities, two in North America and one in Europe. This table shows the importance of cross-sectorial implications and social related aspects that some smart city initiat-

Table 5: Examples of initiatives promoted in three smart cities (Hatzelhoffer et al. 2012, Lee et al., 2014, and city websites).

Cities	(Smart City) Initiatives
Seattle, US	Seattle.gov portal with 20+ language support
	data.seatle.gov allows open data and open government
	Community Technology Planner
	Equitable Justice Delivery System
	Communities Online
	Puget Sound-Off
	Smart Grid
	Automated Metering Infrastructure
	Pacific Northwest Regional Demonstration Project
	Fiber to the premise
	GigU seeks to accelerate the deployment of ultra-high-speed networks to leading U.S. universities and their surrounding communities
	Supervisory Control and Data Acquisition
	Drainage and Waste Water System
	Rain Watch Program
	Field Operations Management System
	Common Operating Picture
	IT Cloud
	Electronic Plan Review System
	Digital Evidence Management System
Quebec City, CA	Zap Quebec providing Wi-Fi internet access
	Text messaging service of snow cleaning information
	Snow cleaning management project: providing sensors at each snow cleaning machine
	Inter-cities network: connecting with major cities of the province of Quebec
	Mobile homepage: developing a mobile version of the city's website
	Infrastructure management system: integrating different information systems to coordinate activities related to infrastructure management
	Open data initiative: making city data open
	Online transportation control system
Friedrichshafen, DE	GPS distress signal, in an emergency, people can send a signal by touching their cell phone
	Mobile Clinic system enables the interactive remote monitoring of patients with chronic heart conditions
	KatCard E-ticketing project enables the non-cash purchase of tickets
	Edunex is a web-based educational platform for schools
	Secured EduKey allows secure access to Edunex biometrically
	Smart Metering provides customers with information about their electricity and gas consumption.
	Digital picture frame has an integrated wireless module and receives digital photos via the Deutsche Telekom network
	CityInfo allows requesting short info on various topics via the SMS information service.
	Multimedia Stations provide information and services free of charge in the areas of city
	Hearing impaired telephones for deaf people access to a sign language interpreting service, using special video telephones
	SZ News adds a local dimension to the Internet Protocol Television information services.
	Tourism portal www.friedrichshafen.info compiles all important information required for a stay in Friedrichshafen.
	With G/On, employees can access their work stations securely from anywhere in the world.
	dDesk allows applications and data are stored on the cloud on a central server.
	T-Mobile emergency number supports the coordination of rescue services in Friedrichshafen.

ives have implemented in practice. For example, in the case of Friedrichshafen, education and integration are deeply considered in several projects. In order to avoid ambiguity with the scope of this paper, the fashion high-tech projects such as Masdar and Songdo are not included in this table. The reader will find extensive literature about these cases in Cugurullo (2013), Greenfield (2013), Liu and Peng (2013), Halpern et al. (2013), and Shwayri (2013).

Conclusions

This paper attempts to clarify the meaning of a concept that is getting increasingly popular—that of the smart city. An in-depth analysis of the literature revealed that the meaning of a smart city is multi-faceted. Descriptions of smart cities are now including qualities of people and communities as well as ICTs. Many elements and dimensions characterizing a smart city emerged from the analysis of the existing literature.

Results show how complicated the measurement of a smart city is. Some attempts to create all-embracing indexes have been reviewed. However, this paper was not meant to define a new framework for the assessment of the smartness of a city, since the authors believe that such an assessment should be tailored to a particular city's vision. A universal fixed system may be difficult to define with the variety of characteristics of cities worldwide. However, it has been made clear that the definitions posed by particular cities calling themselves "smart cities" lack universality.

A smart city assessment must take into account that cities have different visions and priorities for achieving their objectives, but they must promote an integrated development of different aspects, both hard and soft. At the same time, the authors demonstrated the problems of many ranking systems that led to a loss of information on the complexity of smart cities.

This study showed how cities can be considered "smart" by reviewing definitions, components, and measures of performance of cities. We hope that this paper will be useful to policy makers in learning how to identify smart cities, to plan incentives for their development, and to monitor the "smart" progress of their cities.

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Bibliography

S. Alawadhi, A. Aldama-Nalda, H. Chourabi, J.R. Gil-Garcia, S. Leung, S. Mellouli, T. Nam, T.A. Pardo, H.J. Scholl, S. Walker, "Building Understanding of Smart City Initiatives," *Lecture Notes in Computer Science* 7443 (2012) 40–53.

V. Albino, R.M. Dangelico, "Green Cities into Practice," in R. Simpson and M. Zimmermann, eds., *The Economy of Green Cities: A World Compendium on the Green Urban Economy* (Dordrecht, Netherlands: Springer Science Business Media B.V., 2012).

M. Al-Hader, A.R. Mahmud, A.R. Sharif, N. Ahmad, "SOA of Smart City Geospatial Management," Proc. of EMS 2009 - Third UKSim European Symposium on Computer Modeling and Simulation, Athens, Greece, November 25–27, 2009.

S. Allwinkle, and P. Cruickshank, "Creating Smarter Cities: An Overview," *Journal of Urban Technology* 18: 2 (2011) 1–16.

D. Arribas-Bel, K. Kourtit, and P. Nijkamp, "Benchmarking of World Cities through Self-Organizing Maps," *Cities* 31 (2013) 248–257.

T. Bakıcı, E. Almirall, and J. Wareham, "A Smart City Initiative: The Case of Barcelona," *Journal of the Knowledge Economy* 2: 1 (2012) 1–14.

D. Ballas, "What Makes a 'Happy City'?" *Cities* 32: 1 (2013) S39–S50.

M.N. Baqir, and Y. Kathawala, "Ba for Knowledge Cities: A Futuristic Technology Model," *Journal of Knowledge Management* 8: 5 (2004) 83–95.

M. Baron, "Do we need Smart Cities for Resilience?," *Journal of Economics & Management* 10 (2012) 32–46.

J.M. Barrionuevo, P. Berrone, and J.E. Ricart, "Smart Cities, Sustainable Progress," *IESE Insight* 14 (2012) 50–57.

M. Batty, K.W. Axhausen, F. Giannotti, A. Pozdnoukhov, A. Bazzani, M. Wachowicz, G. Ouzounis, and Y. Portugali, "Smart Cities of the Future," *The European Physical Journal Special Topics* 214 (2012) 481–518.

U. Berardi, "Clarifying the New Interpretations of the Concept of Sustainable Building," *Sustainable Cities and Society* 8 (2013a) 72–78.

U. Berardi, "Sustainability Assessments of urban Communities through Rating Systems," *Environment, Development and Sustainability* 15: 6 (2013b) 1573–1591.

A. Caragliu, C. Del Bo, and P. Nijkamp, "Smart Cities in Europe," *Journal of Urban Technology* 18: 2 (2011) 65–82.

R. Carli, M. Dotoli, R. Pellegrino, and L. Ranieri, "Measuring and Managing the Smartness of Cities: A Framework for Classifying Performance Indicators," Proc. of IEEE Systems, Man, and Cybernetics, 2013.

T.M. Chen, "Smart Grids, Smart Cities Need Better Networks [Editor's Note]," *IEEE Network* 24: 2 (2010) 2–3.

H. Chourabi, N. Taewoo, S. Walker, J.R. Gil-Garcia, S. Mellouli, K. Nahon, T.A. Pardo, and H.J. Scholl, "Understanding Smart Cities: An Integrative Framework," Proc. of HICSS, 45th Hawaii Conference, 2289–2297, 2012.

G.L. Cretu, "Smart Cities Design Using Event-driven Paradigm and Semantic Web," *Informatica Economica* 16: 4 (2012) 57–67.

F. Cugurullo, "How to Build a Sandcastle: An Analysis of the Genesis and Development of Masdar City," *Journal of Urban Technology* 20: 1 (2013) 23–37.

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

S. Dirks, *C. Gurdgiev, and M. Keeling, Smarter Cities for Smarter Growth: How Cities Can Optimize Their Systems for the Talent-Based Economy* (Somers, NY: IBM Global Business Services, 2010).

S. Dirks, and M. Keeling, *A Vision of Smarter Cities: How Cities Can Lead the Way into a Prosperous and Sustainable Future* (Somers, NY: IBM Global Business Services, 2009).

L. Edvinsson, "Aspects on the City as a Knowledge Tool," *Journal of Knowledge Management* 10: 5 (2006) 6–13.

J.M. Eger, "Smart Growth, Smart Cities, and the Crisis at the Pump A Worldwide Phenomenon," *I-Ways* 32: 1 (2009) 47–53.

R. Florida, *The Flight of the Creative Class: The New Global Competition for Talent* (New York: Harper Business, 2002).

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

A. GhaffarianHoseini, U. Berardi, N. Dahlan, A. GhaffarianHoseini, and N. Makaremi, "The Essence of Future Smart Houses: From Embedding ICT to Adapting to Sustainability Principles," *Renewable & Sustainable Energy Reviews* 24: (2013) 593–607.

A. GhaffarianHoseini, N. Dahlan, U. Berardi, A. GhaffarianHoseini, and N. Makaremi, "Sustainable Energy Performances of Green Buildings: A Review of Current Theories, Implementations and Challenges," *Renewable & Sustainable Energy Reviews* 25 (2013) 1–17.
R. Giffinger, C. Fertner, H. Kramar, R. Kalasek, N. Pichler-Milanović, and E. Meijers, *Smart Cities: Ranking of European Medium-sized Cities* (Vienna: Centre of Regional Science, 2007).
R. Giffinger, and H. Gudrun, "Smart Cities Ranking: An Effective Instrument for the Positioning of Cities?" ACE Architecture," *City and Environment* 4: 12 (2010) 7–25.
E.L. Glaeser, and C.R. Berry, *Why are Smart Places Getting Smarter? Taubman Centre Policy Brief 2006-2* (Cambridge, MA: Taubman Centre, 2006).
A. Greenfield, *Everyware: The Dawning Age of Ubiquitous Computing* (Boston: New Riders, 2006).
A. Greenfield, *Against the Smart City* (New York: Do Projects, 2013).
L. Guan, "Smart Steps To A Battery City," *Government News* 32: 2 (2012) 24–27.
R.E. Hall, "The Vision of a Smart City." Proc. of the 2nd International Life Extension Technology Workshop, Paris, France, 2000.
O. Halpern, J. LeCavalier, N. Calvillo, and W. Pietsch, "Test- Bed Urbanism," *Public Culture* 25: 2 (2013) 272–306.
S. Hammer, L. Kamal-Chaoui, A. Robert, and M. Plouin, Cities and Green Growth: A Conceptual Framework, OECD Regional Development Working Papers 08, OECD Publishing, 2011.
G.P. Hancke, B.C. Silva, and G.P. Hancke, "The Role of Advanced Sensing in Smart Cities," *Sensors* 13 (2013) 393–425.
C. Harrison, B. Eckman, R. Hamilton, P. Hartswick, J. Kalagnanam, J. Paraszczak, and P. Williams, "Foundations for Smarter Cities," *IBM Journal of Research and Development* 54: 4 (2010) 1–16.
L. Hatzelhoffer, K. Humboldt, M. Lobeck, and C. Wiegandt, *Smart City in Practice: Converting Innovative Ideas into Reality* (Berlin: Jovis, 2012).
R.G. Hollands, "Will the Real Smart City Please Stand Up?" *City: Analysis of Urban Trends, Culture, Theory, Policy, Action 12:* 3 (2008) 303–320.
H.N. Hsich, C.C. Chen, C.Y. Chou, and Y.Y. Chen, "The Evaluating Indices and Promoting Strategies of Intelligent City in Taiwan," Proc. Multimedia Technology, 6704–6709, July 26–28, 2011.
IDA Singapore, "iN2015 Masterplan" (2012) <http://www.ida.gov.sg/~/media/Files/Infocomm%20Landscape/iN2015/Reports/realisingthevisionin2015.pdf>
T. Ishida, "Digital City Kyoto," *Communications of the ACM* 45: 7 (2002) 78–81.
R.M. Kanter, and S.S. Litow, Informed and interconnected: A manifesto for smarter cities, Harvard Business School General Management Unit, 09-141, 2009.
R. Kitchin, "The Real-time City? Big Data and Smart Urbanism," *GeoJournal* 79: 1 (2014) 1–14.
C. Klein, and G. Kaefer, "From Smart Homes to Smart Cities: Opportunities and Challenges from an Industrial Perspective," Proc. of the 8th International Conference, NEW2AN and 1st Russian Conference on Smart Spaces, SMART 2008, St. Petersburg, Russia, September 3–5, 2008.
N. Komninos, *Intelligent Cities: Innovation, Knowledge Systems and Digital Spaces* (London: Spon Press, 2002).
N. Komninos, "Intelligent Cities: Variable Geometries of Spatial Intelligence," *Intelligent Buildings International* 3: 3 (2011) 172–188.
N. Komninos, M. Pallot, and H. Schaffers, "Smart Cities and the Future Internet in Europe," *Journal of the Knowledge Economy* 4: 2 (2013) 119–134.
K. Kourtit, and P. Nijkamp, "Smart Cities in the Innovation Age," *Innovation: The European Journal of Social Science Research* 25: 2 (2012) 93–95.
K. Kourtit, P. Nijkamp, and D. Arribas, "Smart Cities in Perspective – A Comparative European Study by Means of Self-organizing Maps," *Innovation: The European Journal of Social Science Research* 25: 2 (2012) 229–246.
G.C. Lazaroiu, and M. Roscia, "Definition Methodology for the Smart Cities Model," *Energy* 47: 1 (2012) 326–332.
J.H. Lee, R. Phaal, and S. Lee, "An Integrated Service-device-technology Roadmap for Smart City Development," *Technological Forecasting and Social Change* 80: 2 (2013) 286–306.
J.H. Lee, M.G. Hancock, and M. Hu, Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco, Technological Forecasting and Social Change, in press, 2014.
L. Leydesdorff, and M. Deakin, "The Triple-Helix Model of Smart Cities: A Neo-Evolutionary Perspective," *Journal of Urban Technology* 18: 2 (2011) 53–63.
P. Liu, and Z. Peng, "Smart Cities in China, IEEE Computer Society Digital Library" (2013) <http://doi.ieeecomputersociety.org/10.1109/MC.2013.149>
P. Lombardi, S. Giordano, H. Farouh, and W. Yousef, "Modelling the Smart City Performance," *Innovation: The European Journal of Social Science Research* 25: 2 (2012) 137–149.

A. Mahizhnan, "Smart Cities: The Singapore Case," *Cities* 16: 1 (1999) 13–18.
M.L. Marsal-Llacuna, J. Colomer-Llinàs, and J. Meléndez-Frigola, "Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative, Technological Forecasting and Social Change" (2014).
N. Mitton, S. Papavassiliou, A. Puliafito, and K.S. Trivedi, "Combining Cloud and Sensors in a Smart City Environment," *EURASIP Journal on Wireless Communications and Networking* 247 (2012) 1–10.
K. Mori, and A. Christodoulou, "Review of Sustainability Indices and Indicators: Towards a New City Sustainability Index (CSI)," *Environmental Impact Assessment Review* 32: 1 (2012) 94–106.
T. Nam, and T.A. Pardo, "Conceptualizing Smart City with Dimensions of Technology, People, and Institutions," Proc. 12th Conference on Digital Government Research, College Park, MD, June 12–15, 2011.
P. Neirotti, A. De Marco, A.C. Cagliano, G. Mangano, and F. Scorrano, "Current Trends in Smart City Initiatives: Some Stylised Facts," *Cities* 38 (2014) 25–36.
M. O'Grady, and G. O'Hare, "How Smart Is Your City?" *Science* 335: 3 (2012) 1581–1582.
H. Partridge, "Developing a Human Perspective to the Digital Divide in the Smart City," Proc. of the Biennial Conference of Australian Library and information Association, Queensland, Australia, Sep 21–24, 2004.
K.A. Paskaleva, "The Smart City: A Nexus for Open Innovation?" *Intelligent Buildings International* 3: 3 (2011) 153–171.
J.M. Shapiro, "Smart Cities: Quality of Life, Productivity, and the Growth Effects of Human Capital," *Review of Economics & Statistics* 88: 2 (2006) 324–335.
S.T. Shwayri, "A Model Korean Ubiquitous Eco-City? The Politics of Making Songdo," *Journal of Urban Technology* 20: 1 (2013) 39–55.
M. Thite, "Smart Cities: Implications of Urban Planning for Human Resource Development," *Human Resource Development International* 14: 5 (2011) 623–631.
M. Thuzar, "Urbanization in SouthEast Asia: Developing Smart Cities for the Future?," *Regional Outlook* (2011) 96–100.
A.M. Townsend, *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia* (New York: W.W. Norton & Company, 2013).
C. Turcu, "Re-thinking Sustainability Indicators: Local Perspectives of Urban Sustainability," *Journal of Environmental Planning and Management* 56: 5 (2013) 695–719.
UN, United Nations, "World Urbanization Prospects: The 2007 Revision Population Database" (2008) <http://esa.un.org/unup/>
A. Vanolo, "Smartmentality: The Smart City as Disciplinary Strategy," *Urban Studies* 51: 5 (2014) 883–898.
D. Washburn, U. Sindhu, S. Balaouras, R.A. Dines, N.M. Hayes, and L.E. Nelson, *Helping CIOs Understand "Smart City" Initiatives: Defining the Smart City, Its Drivers, and the Role of the CIO* (Cambridge, MA: Forrester Research, 2010).
J.V. Winters, "Why are Smart Cities Growing? Who Moves and Who Stays," *Journal of Regional Science* 51: 2 (2011) 253–270.
E. Woods, "Smart Cities. Infrastructure, Information, and Communication Technologies for Energy, Transportation, Buildings, and Government: City and Supplier Profiles, Market Analysis, and Forecasts, Pike Research" (2013).
T. Yigitcanlar, and S.H. Lee, Korean ubiquitous-eco-city: A smart-sustainable urban form or a branding hoax?, Technological Forecasting and Social Change, in press, 2014.
T. Yigitcanlar, K. O'Connor, and C. Westerman, "The Making of Knowledge Cities: Melbourne's Knowledge-based Urban Development Experience," *Cities* 25: 2 (2008) 63–72.
G.S. Yovanof, and G.N. Hazapis, "An Architectural Framework and Enabling Wireless Technologies for Digital Cities & Intelligent Urban Environments," *Wireless Personal Communications* 49: 3 (2009) 445–463.
S. Zygiaris, "Smart City Reference Model: Assisting Planners to Conceptualize the Building of Smart City Innovation Ecosystems," *Journal of the Knowledge Economy* 4: 2 (2013) 217–231.