Smart cities: definitions, dimensions, and performance

Vito Albino

Department of Mechanics, Mathematics and Management
Politecnico di Bari
Viale Japigia, 182 - 70126 - Bari, Italy

Umberto Berardi

Department of Civil and Environmental Engineering
Worcester Polytechnic Institute
100 Institute Road - 01609 - Worcester (MA), USA

Rosa Maria Dangelico*

Department of Computer, Control, and Management Engineering
"Antonio Ruberti"
Sapienza - University of Rome
Via Ariosto, 25 - 00185 - Rome, Italy

** Corresponding author*

Structured Abstract

Purpose – The concept of smart city is getting more and more relevant for both academics and policy makers. Despite this, there is still confusion on what a smart city is and several similar terms are often used interchangeably. This paper aims at clarifying the meaning of the word "smart" in the context of cities and to identify the main dimensions and elements characterizing a smart city. Furthermore, performance measures of a smart city will be identified.

Design/methodology/approach – We propose an approach based on an in-depth literature review of relevant studies as well as of official documents of international institutions.

Originality/value – This paper will bring clarity to the meaning and characteristics of a smart city. The different metrics of urban smartness will be reviewed to show the need for a shared definition of what is a smart city, which are its features and which performance it has in comparison to traditional cities.

Practical implications – The results of this paper could be useful for policy makers to identify smart cities, to plan incentives for their development and, through the identified measures of performance, to monitor the progresses of cities towards getting smarter cities.

Keywords – smart city, sustainability, urban economy

Paper type – Academic Research Paper

1 Introduction

In last two decades the concept of smart city has become more and more popular in scientific literature and international policies. To understand the concept it is important to recognize why cities are considered the key element in strategic plans for the future.

The main reason seems related to the prime role of cities in the social and economic aspects of people worldwide, and in the huge impact on environmental sustainability (Mori and Christodoulou, 2012). According to the United Nations Population Fund, 2008 marked the year when more than 50% of all people, 3.3 billion, lived in urban areas, a figure expected to rise to 70% by 2050 (UN, 2008): in Europe, 75% of the population already lives in urban areas, and by 2020 the number is expected to reach 80% (EEA, 2006). The importance of urban areas is a global phenomenon, as confirmed by the diffusion of megacities of more than 20 million people which are gaining ground in Asia, Latin America and Africa (UN, 2008). As a result, most resources are nowadays consumed in cities worldwide. This fact contributes to the economic and social importance of cities, but also to their poor environmental sustainability.

Awareness of this trend pushes the research of new ways to accommodate increasing requests and urgent problems; for example, physical risks, such as deteriorating conditions in air and transportation, and economic risks, such as unemployment.

In this type of world, cities consume 60-80% of energy worldwide and therefore are responsible for large shares of GHG emissions. However, the lower the urban density, the more energy is consumed for electricity and transportation. CO_2 emissions per capita drop significantly as urban areas densify (Hammer et al. 2011).

This situation requires cities to find new and smarter ways to manage new challenges. Cities metabolism generally consists of the input of goods and the output of wastes with unavoidable and consistent negative externalities, which amplifies social and economic problems (Turcu, 2012). 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 city sustainability have promoted a more anthropocentric approach according to which, cities should respond to people's needs through sustainability solution for social and economic aspects (Turcu, 2012).

Let us consider that cities with high urban density can rely on transportation linkages, mixed land uses, and high-quality urban services which can have long-term positive effects on the economy due to technological innovation (for instance, high-quality, more-efficient public transport that responds to economic needs and better connects labour with employment, thus increasing firms' productivity).

Then, new approaches to urban service provision arise, such as that of smart cities, where harnessing technology, including ICT, efficient service delivery is offered.

However, the concept of smart city is far from being limited to technological aspects and, together with the growing relevance of the smart city concept, definitions and meanings are proliferating, generating confusion on the essence of a smart city. This confusion can represent an important obstacle to policy makers, making it difficult to

recognize smart cities, measure the "smartness" performance of a city, as well as put in place appropriate policies to incentive the development of smart cities.

In this paper we seek to advance our knowledge on what a smart city is, which are its key elements, and how its performance can be evaluated.

In particular, the paper is structured as follows. First, we review the main definitions of "smart city", highlighting the different meanings given to the concept and the perspectives through which it has been studied. Then, we analyze the key elements and dimensions of a smart city. After that, we focus on the measures of performance of a smart city. Finally we conclude discussing the main findings and providing implications from the study.

2 Definitions of smart city

Many definitions of smart city exist and a range of conceptual variants have been adopted by replacing "smart" with other 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 smart city nor a one-size-fits-all definition of smart city.

Hollands (2008) recognized smart city as an "urban labelling" phenomenon, and asking to real smart city to stand up, it emphasis the many aspects which are hidden behind self-declaratory attribution of this label.

Nam and Pardo (2012) review the meaning of the term "smart" in the "smart city context". In marketing language, smartness is centered on a user perspective. Because of the need for appeal to a broader base of community members; "smart" is user-friendly and serves better than the more elitist term "intelligent", which is limited to having a quick mind and being responsive to feedback. This interpretation suggests that "smart" is more than "intelligent", and the smartness is realized only when the system adapts itself to the user needs.

In the urban planning field, the smartness is treated as a normative claim and an ideological dimension, 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, sound economic growth, and better quality of life for their citizens (Center on Governance, 2003).

Table 1 reports some of the definitions of "smart city" proposed in the literature, providing an idea of the many meanings that a smart city has.

Table 1: Definitions of “smart city”.

Definition	Source
A Smart City is a city well performing in a forward-looking way in six “smart” characteristics, built on the ”smart” combination of endowments and activities of self-decisive, independent and aware citizens.	www.smart-cities.eu
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. (2009)
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	Giffinger et al. (2007)
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)
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 on the role of human capital/education, social and relational capital, and environmental issues is often indicated by the notion of smart city	Lombardi et al. (2012)
The use of Smart Computing technologies to make the critical infrastructure components and services of city-which include city administration, education, healthcare, public safety, real estate, transportation, and utilities- more intelligent, interconnected, and efficient	Washburn et al. (2010)
“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.” p. 50	Barrionuevo et al. (2012)
“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.” p.25	Guan (2012)
Information technologies represent the key concept. The vision of an intelligent city is not confined to economic excellence that can be led by information technologies, but an integral part of this vision is its concern for the quality of life for the ordinary citizen. [reworded sentences]	Mahizhnan (1999)
“The fuel crisis gives us further excuse to start doing something to transform our cities for the new global – internet driven – age: a ‘smart community’. While a ‘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	Eger (2009)

, 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." pp. 47-48 "[…] a truly "Smart Community" is a community that has made a conscious effort to use information technology to transform life and work within its region in "significant and fundamental," rather than incremental ways." p.50 "Cities of the Future – Athens in the Information Age – will be truly smart communities, sustainable, healthy, culturally strong, diverse, and exciting places to live and work and play." p.53	
"[…] 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." p.3	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." p. 57	Gabriel Cretu (2012)
"[…] the term is not used in a holistic way describing a city with certain attributes, but is used for various aspects which range from Smart City as an IT-district to a Smart City regarding the education (or smartness) of its inhabitants." p. 10 "A Smart City is a city well performing in a forward-looking way in these six characteristics [economy, mobility, environment, people, living, governance], built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens." p. 11	Giffender et al. (2007)
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)." p. 93	Kourtit and Nijkamp (2012)
"Smart cities have a 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." p. 232	Kourtit et al. (2012)
Smart is used as a synonym of creative. "[…] 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." p. 623 "The nexus of competitive advantage has […] shifted to those regions that can generate, retain, and attract the best talent." p. 624	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	Thuzar (2011)

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." p. 96	
"[…] I consider "smart cities" to be metropolitan areas with a large share of the adult population with a college degree."	Winters (2011)
(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 (2006)
The term "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 (2012)
". . .territories with a high capacity for learning and innovation, which is built in to the creativity of their population, their institutions of knowledge production, and their digital infrastructure for communication."	Holland (2008)
a city to be 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. (2012)

Table 1 shows that the concept of smart city is particularly related to that of sustainability and it does not referee to the diffusion of ICT but it moves from and looks at people and community needs.

Nam and Pardo (2012) have recently discussed about the difference between the concept of smart city and other related terms along the three categories of technology, people and community.

From the technology perspective, smart city has been defined as a city with a great presence of ICT technologies. These had permeated into the commercial application of intelligent-acting products and services, artificial intelligence, and thinking machines. Smart homes and smart buildings are example of systems equipped with a multitude of mobile terminals and embedded devices as well as connected sensors and actuators (Klein and Kaefer, 2008). In this context a smart city becomes the extension of a smart space to the entire city scale.

However, confusion related to the technology category of smart cities derives from the existence of similar terms related to the smart city concept, such as digital, intelligent, virtual, and ubiquitous. These terms referee to more specific and less inclusive levels of a city, so that the concept of smart city often include and extend them.

A digital city refers to "a connected community that combines broadband communications infrastructure; a flexible, service-oriented computing infrastructure based on open industry standards and, innovative services to meet the needs of governments and their employees, citizens and businesses" (Ishida, 2002). The goal of a digital city is to create an environment for information sharing, collaboration, interoperability and seamless experiences for all inhabitants anywhere in the city.

The notion of an intelligent city emerges at the crossing of the knowledge society with the digital city. According to Komninos (2011), intelligent cities make conscious efforts to use information technology to transform life and work in significant and fundamental rather than incremental ways. The label intelligent city reminds the ability to support learning, technological development, and innovation procedures in cities; in this sense, every digital city is not necessarily intelligent, but every intelligent city has digital components, but the people and community perspective is still not included as in a smart city.

In a virtual city, city functions are implemented in a cyberspace. The city becomes a hybrid concept which consists of a reality with its physical entities and real inhabitants and a parallel virtual city of counterparts of real entities and people.

A ubiquitous city is an extension of digital city concept in terms of ubiquitous accessibility and infrastructure. It makes the ubiquitous computing available to the urban elements. Its characteristics is the creation of an environment where any citizen can get any services anywhere and anytime through any devices. The ubiquitous city is quite different from the well-known virtual city: while the virtual city reproduces urban elements by visualizing them within the virtual space, ubiquitous city is created by the computer chips or sensors inserted to those urban elements (Lee et al., 2013).

From the "people" perspective, creativity is recognized as a key driver of smart city, and thus people, education, learning and knowledge have a central role in a smart city. The expansive notion of smart city includes creating a climate suitable for an emerging creative class. Social infrastructure (intellectual capital and social capital) is indispensable endowment to smart cities and relates to people and relationships (Nam and Pardo, 2012). Smart people generates and benefits from social capital, so that smart city acquires the meaning of a mix of education/training, culture/arts, and business/commerce with hybrid social enterprise, cultural enterprise, and economic enterprise (Winters, 2010). Focusing on education, Winters (2010) found that a smart city is a center of higher education and better-educated individuals or of skilled workforces. Smart places are getting smarter while other places getting less smart because such places act as a magnet for creative people and workers. A smart city is a humane city that has multiple opportunities to exploit its human potential and lead a creative life.

A related term to smart city, along this perspective, is knowledge city. This is a city designed to encourage the nurturing of knowledge. The notion of knowledge city is interchangeable to a certain degree with similar evolving concepts such as educating city. The buzz concept of being clever, smart, skilful, creative, networked, connected, and competitive becomes a key ingredient of knowledge-based urban development and hence of a smart city (Dirk et al., 2010).

The third perspective of a smart city is that of "community". The institutional factor of a smart city reminds the concept of smart communities. A smart community is defined as a community of common or shared interest, whose members, organizations and governing institutions are working in partnership to use IT to transform their circumstances. This means that the community created within a smart city needs to feel the desire to promote a smart growth. The concept of smart growth was largely used in the 1990s, as a strong government- and 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 facilities cost (Nam and Pardo, 2012), and is still a key objective of the flourishing concept of smart city.

3 Dimensions of a smart city

The attribute of smart is often not attributed to a city holistically (as a whole smart city) but it is separated in many features of the city which are singularly considered "smart".

Giffinger et al. (2007) identified four fields of realization of a "smart city": industry, education, participation, and technical infrastructure.

A recent project conducted by the Centre of Regional Science at the Vienna University of Technology identifies six main "axes" (dimensions) along which a ranking of 70 European middle size cities was made. These axes are: smart economy, smart mobility, smart environment, smart people, smart living, and smart governance. These six axes connect with traditional regional and neoclassical theories of urban growth and development. In particular, the axes are based -respectively -on theories of regional competitiveness, transport and ICT economics, natural resources, human and social capital, quality of life, and the participation of society members in cities.

Lombardi et al. (2012) have used and investigated further each dimension and have referred it to a different aspects of urban life, as reported in table 2.

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

Dimension 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

Komninos (2002, p. 1) in his attempt to delineate the features of an intelligent city indicated four possible realization of it (attention should be paid to the less inclusive reference to "intelligent" instead of "smart" city). The first concerns the application of a wide range of electronic and digital, which effectively work to conflate the term with ideas about the cyber, digital, wired, informational or knowledge based city. The second

is the use of information technology to transform life and work within a region in significant and fundamental ways. The third is as embedded information and communication technologies in the city, and the fourth is as spatial territories that bring ICTs and people together to enhance innovation, learning, knowledge and problem solving.

The separation of the concept of smart city in the different dimensions shows that the concept is often not used in a holistic way, but different aspects of a city are evaluated.

In relation to the economic interpretation of smart cities this term has often been referred to the presence of smart industries. This implies industries in the fields of ICT as well as industries employing ICT in their production processes. The name "smart city" is hence used for business parks or districts comprising companies within this field (Giffinger et al., 2007, Caragliu et al., 2009).

The term "smart city" is sometimes used to discuss the use of ICT for modern transport technologies. Smart systems improve urban traffic and inhabitants' mobility.

Aspects referring to the environment behaviour of a city life such as green, efficiency and sustainable energy are considered in Komninos (2007), Giffinger et al. (2007) and Caragliu et al. (2009).

Smart city integrates technologies, systems, infrastructures services, and capabilities into an organic network that is sufficiently complex for unexpected emergent properties to develop. Integrative service of smart city faces challenges as well as opportunities. The perception of technology in smart city initiatives stresses integration of systems, infrastructures and services mediated through enabling technologies. Technological innovation is a means to smart city, not an ends. IT is just a facilitator for creating a new type of innovative environment, which requires the comprehensive and balanced development of creative skills, innovation-oriented institutions, broadband networks, and virtual collaborative spaces (Komninos, 2009).

Towards more progressive smart cities, cities should start with people from the human capital side, rather than blindly believing that IT itself can automatically transform and improve cities (Holland, 2008). Stronger approaches to awareness, education and leadership offer services that are accessible to all of citizens, get rid of barriers related to language, culture, education, skills development, and disabilities.

The smart city concept has also been viewed as a large organic system stressing the fact that the organic integration of systems and the interrelationship between a smart city's core systems make a smart city. A smarter 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, 2012). However, infusing intelligence into each subsystem of a city, one by one is not enough to become a smarter city, as this should be treated as an organic whole (Kanter and Litow, 2009).

From the discussion of conceptual definition of smart city, key conceptual components of smart city, were categorized by Nam and Pardo (2012) in the following

core factors: technology (infrastructures of hardware and software), people (creativity, diversity, and education), and institution (governance and policy). Given the connection between the factors, a city is smart when investments in human/social capital and IT infrastructure fuel sustainable growth and enhance a quality of life, through participatory governance (Nam and Pardo, 2012).

Technology is key to being a smart city because of the use of ICT to transform life and work within a city in significant and fundamental ways. A smart city provides interoperable, internet-based government services that enable ubiquitous connectivity to transform key government processes, both internally across departments and employees and externally to citizens and businesses

The smart people concept comprises various factors like affinity to lifelong learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism or open-mindedness, and participation in public life. Problems associated with urban agglomerations can be solved by means of creativity, human capital, cooperation among relevant stakeholders, and their bright scientific ideas and "smart solutions". The label smart city therefore points to clever solutions by creative people.

Smart governance means various stakeholders' (especially citizens') engagement in decision making and public/social services. IT-mediated governance, so called e-governance, is fundamental to enabling smart city by bringing citizens to a smart city initiative and keeping the decision and implementation process transparent. The central spirit of governance is a citizen-centric, citizen-driven approach.

Table 3 reports the key elements and dimensions of a smart city.

Table 3: Key elements and dimensions of a smart city.

Key elements/ dimensions	**Source (author, year)**
"[…] five types of capital that contribute toward a city's intelligence: • 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)
• IT education • IT infrastructure • IT economy • Quality of life	(Mahizhnan 1999)
• technology • economic development • job growth • increased quality of life	(Eger 2009)
• smart economy	(Giffender et al.

• smart mobility • smart environment • smart people • smart living • smart governance	2007)
• 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)
• 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 • economo-techono-social issues of the environment • interconnection • instrumentation • intergration • applications • innovations	(Nam and Pardo 2012)

The characteristics proper to a smart city that tend to be common to many of the previous features are indicated by Caragliu et al. (2012):

1. the utilization of networked infrastructure to improve economic and political efficiency and enable social, cultural, and urban development;

2. an underlying emphasis on business-led urban development;

3. a strong focus on the aim of achieving the social inclusion of various urban residents in public services;

4. a stress on the crucial role of high-tech and creative industries in long-run urban growth;

5. profound attention to the role of social and relational capital in urban development;

6. social and environmental sustainability as a major strategic component of smart cities.

4 Measures of performance

Measuring the performance of a city as a smart city is a complicated issue.

Further, based on the meaning(s) given to the concept of smart city, appropriate measures should be adopted. Several measures, indexes, and methods have been developed so far.

The University of Vienna (Giffender et al., 2007), developed an assessment metric to rank European medium-sized cities. This metric uses specific indicators for each of the six identified dimensions of a smart city: smart economy, smart people, smart

governance, smart mobility, smart environment, and smart living. For example, smart mobility is measured through local accessibility, international accessibility, availability of ICT-infrastructure, sustainable, innovative and safe transport system.

Another system is that used by the Intelligent Community Forum (ICF) which annually announces cities awarded as Smart21 Communities. This metric is based on five factors which have to be fulfilled to be an intelligent community (i.e., broadband connectivity, knowledge workforce, digital inclusion, innovation, and marketing and advocacy). Unfortunately, data and criteria behind the awards are not commonly disseminated as the Forum has often been used in a self-declaratory way.

More recently Caragliu et al. (2012) developed a measurement system, identifying six layers and levels of a smart city.

Layer 0: *The City Layer*. Smart cities must start with the "city" not the "smart", emphasizing that smart city notions must be grounded to the context of a city. This layer conveys the traditional components present in every city.

Layer 1: *The Green City Layer*. The green city layer is inspired from new urbanization theories raised by Greenburg and LEED initiatives.

Layer 2: *The Interconnection Layer*. The green city layer is integral to the smart city concept referring not only to "infrastructural green islands" but also to city-wide diffusion of green economies.

Layer 3: *The Instrumentation Layer*. Cities, as urban machines of real events, require real-time system response. They comprise of real-time connections outlets such as radiofrequency transmitters, traffic signals, streets, smart meters, infrastructure sensors, and traffic and transit sensors.

Layer 4: *The Open Integration Layer*. Smart cities applications should be able to intercommunicate, and share among others data, content, and services. A key success factor for smart environments is the provision of open and distributed information storage, for all the embedded or not systems, implemented with different technological platforms.

Layer 5: *The Application Layer*. Smart cities mirror the real-time city operation pulse as system with systems. Cities are also being empowered technologically, as the core systems on which they are based become instrumented and interconnected, enabling new levels of intelligently responsive operation.

Layer 6: *The Innovation Layer*. Smart cities create a fertile innovation environment for new business opportunities. First is the need to transform the quality and efficiency of public infrastructures and services. Secondly, a smart city must be an attractive place for doing business. Emerging technologies push for instrumented, interconnected, and intelligent in nature cities to accelerate their journey towards sustainable prosperity by making use of new "smart" solutions and management practices.

A methodology to assess and compare smart city models has been recently proposed by Lazaroiu and Roscia (2012). They selected a high set of indicators for computing "the smart city" index. The index is proposed to help the distribution of funding by the European Commission in its strategic energy plan for the 2020 European strategy. The proposed indicators are not homogeneous and contain high amount of information, which

raises the problem of information availability and difficulty in assigning weights for the considered indicators. Moreover, the proposed approach uses a procedure based on fuzzy logic which allows defining a set of weights for combining the different criteria. Fuzzy methods have been often used to determine the relative importance of the indicators and sub-indicators. This method deals with medium-sized cities and their perspectives for development. This because the large majority of the urban population lives in these types of cities, and the challenges associated with them are still unexplored, whereas medium-sized cities are less well equipped in terms of critical mass, resources and organizing capacity. The analysis is based on 18 indicators as reported in table 4.

Table 4: Indicators for smart cities assessment as reported in Lazaroiu and Roscia (2012).

Indicators
Pollution
Innovative spirits
CO_2
Transparent governance
Sustainable resource management
Separated littery
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

Another model to measure smartness of a city has been recently proposed by Lombardi et al. (2012). These used the modified version of the triple helix model, a reference framework for the analysis of knowledge-based innovation systems, which relate the multiple and reciprocal relationships between the three main agencies in the process of knowledge creation and capitalization: universities, industry and government (Etzkowitz, 2008). To the previous three main agencies of knowledge creation, the authors added the civil society (determining a "four helices model"), and for each of the four different drivers of innovations, they indicated the possible indicators of a smart city (Lombardi et al., 2012). This framework of analysis was hence populated with 60 indicators selected after a literature review which included EU projects reports and the Urban Audit dataset, and indicators selected from 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 (Lombardi et al., 2012).

Before concluding this section it should be mentioned that several sustainability assessment metrics of cities may partially be considered as assessment metrics for a smart city (Häkkinen, 2007, Sharifi and Murayama, 2012). Pope et al. (2004) and Tanguay et al. (2010) have offered a review of available indicators for measuring sustainability of cities. They showed that most of the currently used indicators are characterized by a strong environmental approach. This is evident considering indices such as the Ecological Footprint, the Water Footprint, the Environmental Sustainability, and the Environmental Vulnerability of cities.

5. Discussion and conclusion

This paper is an attempt to explain and clarify the meaning of a concept that is getting more and more popular: the concept of "smart city". An in-depth analysis of the literature revealed that the meaning of smart city is multi-faceted and that definitions for the concept are proliferating. Starting from the original meaning of a city in which ICTs play a key role to improve quality of life and achieve economic excellence (Mahizhnan, 1999), the definitions of smart city evolved along three main directions, representing the perspectives through which the concept has been studied: technology, people, and community. According with the large number of definitions, many elements and dimensions characterizing a smart city emerged from the analysis of the literature. All of them should be carefully measured to assess the performance of a city as a "smart city", and this highlights how complicated the issue of measurement is. Some attempts to create all-embracing indexes have been done so far. However, this study highlights that the development and implementation of appropriate measures is still at a nascent stage, and that a generally accepted measurement model is still lacking.

In terms of policy implications, this study can support policy makers to: (i) identify cities that can be considered smart (along one or more dimensions), (ii) develop incentives and tools for the development of smart cities, and (iii) monitor the progresses of cities towards "smartness" along several dimensions.

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