Smart cities: definitions, dimensions, performance, and initiatives

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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
Tel. +39 348 4967185
E-mail: uberardi@wpi.edu

Rosa Maria Dangelico

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

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Abstract

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 as several similar terms are often used interchangeably. This paper aims at clarifying 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, which 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.

1. 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 a key element 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% 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 the number is expected to reach 80% 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, most resources are nowadays consumed in cities worldwide, contributing to their economic importance, but also to their poor environmental performance. Cities consume between 60% and 80% 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). The awareness of previous aspects pushes the research of identifying new ways to accommodate increasing requests and urgent problems of cities among which physical risks, such as deteriorating air conditions, and economic risks, such as the unemployment.

Cities' metabolism generally consists of the input of goods and the output of waste with consistent negative externalities, which amplify 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 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, 2012, Berardi, 2013).

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 labour with employment are considered a key element for city growth. Many of the new approaches related to urban service have been based on harnessing technologies, including ICT. All together, these approaches have supported the request for the city to be smart.

The concept of smart city is far from being limited to technological aspects. With its growing relevance, definitions and meanings of smart city are proliferating in many sectors, generating confusion on its essence. This confusion can represent an important obstacle to policy makers, making it difficult to recognize smart cities, measure the "smartness" of a city, as well as put in place appropriate policies to incite the development of smart cities.

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. This paper 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; section 3 analyzes the key dimensions of a smart city; section 4 focuses on the measures of performance of a smart city; section 5 reports some experiences of smart city; finally, section 6 discusses the main findings of this study.

2. Definitions of smart city

Many definitions of smart city 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 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 Smarted 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 the latter understanding, the smart city should have a strong governance-oriented approach which emphasizes the role of social capital and relations in the urban development (Hatzelhoffer et al., 2013). 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 which 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, the smartness is a user-friendly term that serves better than the more elitist term “intelligent”, which is 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 a 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 which 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”. The table shows that this concept is sometimes related to that of “broad sustainability” (Berardi, 2013). However, the table clarifies that the smart city does not limit anymore 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 only final scope to enhance the quality of life.

Table 1 Definitions of smart city.

Nam and Pardo (2011) discussed the difference between the concept of smart city and other related terms, such as digital, intelligent or ubiquitous city, along the three categories of technology, people and community. From the technology perspective, a smart city is a city with a great presence of ICTs applied to critical infrastructure components and services (Washburn et al., 2010). ICTs 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 (GhaffarianHoseini 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 amount of pertaining 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, the 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).

The technology perspective of a smart city is highly present in most of the reports produced by corporations of ICTs (such as IBM, Cisco Systems, and Siemens AG). For them, the philosophical underpinning and goal of the smart city concept is to build an optimally regulate and control resources by means of autonomous IT systems. This statement has recently been criticized by Greenfield (2013) in the book *Against the Smart City*. Here, the authors shows that examples of smart cities such as Songdo (Korean), Masdar City (UAE) or PlanIT Valley (Portugal), disregard actual knowledge about how cities really function, and represent "empty" spaces, where techno-utopian concept led by large ICT corporations and their government client-sponsors, have led to forgot the value of complexity, of unplanned scenarios, and mix uses. The current interpretations of the technology perspective have hence the limit of considering a fixed goal for a city and to base this on a corporate perspective where citizens become customers (Greenfield, 2013). Several authors have hence shown how the technology perspective should encourage an open access to data, rejecting to adapt citizens' life to technical standards (Cugurullo, 2013, Kitchin, 2014, Vanolo, 2014).

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 city often include and extend them. 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 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 extensive accessibility. It makes the ubiquitous computing available to the urban elements everywhere (Greenfield, 2006). 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 the 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 to the concept of smart city. For example, the creativity is recognized as a key driver of smart city, and thus education, learning and knowledge have a central role in a smart city (Thuzar, 2011). The notion of smart city includes creating a climate suitable for an emerging creative class (Florida, 2002, 2005). The social infrastructure, such as the 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 a magnet 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 educated labour force is available. The buzz concept of being clever, smart, skilful, creative, networked, connected, and competitive becomes a key ingredient of knowledge-based urban development (Dirks et al., 2010).

A related term to smart city, along this perspective, is that of knowledge city. This is a city designed to encourage the nurturing of knowledge (Edvinsson, 2006, Baqir and Kathawala, 2008, Yigitcanlar et al., 2008). Extensive literature on this concept has been published in the last few years.

The development of a knowledge-based urban environments has recently been spurred by the advancement of new clouding technologies for urban monitoring systems. In fact, as sensors collect terabytes of information, data needs 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 to obtain any type of data acquired from different sensing infrastructures. This again becomes the starting point for technocratic approaches to the policies and ideas for creating a smart city. However, it is important to understand that the new perspectives of knowledge city request and invite governments to favour bottom-up schemes process of knowledge diffusion more than top-down systems, typical of technocratic view promoted by some governments under the pressure of big IT corporates (Allwinkle and Cruickshank, 2011). The large-scale diffusion of new sensors in devices such as smartphones, allows individuals to share data collectively and extract information instantly. This new frontier has inspired and promoted concepts such as Internet of Things, and more recently led the discussion about Future Internet.

The third category used by Nam and Pardo (2011) for clarifying the concept of smart city is that of the 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, 2013). 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 facilities cost (Eger, 2009). As it is evident, these goals are among the reasons for looking at smart cities nowadays.

The lack of a unique definition of smart city suggests to investigate the domains in which it has been divided. This analysis may surely help indicate the relative weight of hard and soft domains, and will help to generate a better understanding of the characteristics and future trends. Hard domains are the city settings in which the vision of a city that senses and acts can be the most applicable; these refer to buildings, energy grids, natural resources, water management, waste management, mobility, and logistics (Neirotti et al, 2014). On the other side, in soft domains, ICT has a more limited role, as it evident considering areas such as education, culture, policies innovation and social inclusion, and e-government.

3. Dimensions of a smart city

Dirks and Keeling (2009) stress the importance of an organic integration of the different systems composing a smart city (transportation, energy, education, health care, buildings, physical infrastructure, food, water, and public safety) as the relationships among these systems are fundamental in creating a smart city. Researchers that support this integrated view of a smart city often remind that in a dense environment, like that of cities, no system operates in isolation. Kanter and Litow (2009) stressed 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 to clarify the argument of a smart city have separated this concept in many features and dimensions, justifying this decision with the complexity of managing the concept of smart city in a holistic way.

Komninos (2002, 2011) in his attempt to delineate the features of an intelligent city, indicated it 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 ICTs in the city infrastructure; the fourth is to bring ICTs and people together to enhance innovation, learning, and knowledge.

More recently, Giffinger et al. (2007) identified four fields of realization 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 dimensions (Giffinger and Gudrun, 2010). These dimensions are smart economy, smart mobility, smart environment, smart people, smart living, and smart governance. These dimensions 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, respectively. Particularly interesting in the previous list of dimensions of a smart city is the inclusion of the "quality of life". This dimension reminds 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 an overriding dimension (Shapiro, 2006).

Lombardi et al. (2012) have further investigated the previously previous six dimensions and have associated to them different aspects of the urban life, as reported in table 2. The smart economy has hence been referred to the presence of industries in the fields of ICT or employing ICT in their production processes. The 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).

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

According to Nam and Pardo (2011), key dimensions of smart city together with the technology components are the people (creativity, diversity, and education) and the institutions (governance and policy). Connections exist between these last two factors, 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 ICTs, these are surely 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 smart city may create risks for the independency of governments.

Smarter cities start from the human capital side, rather than blindly believing that the ICT itself can automatically create a smart city (Shapiro, 2006, Holland, 2008). Approaches towards education and leadership in a smart city should hence 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 to generate clever solutions of urban problems through creative people.

Smart governance means various stakeholders are engaged in decision making and public services. ICT-mediated governance, also called e-governance, is fundamental to bring smart city initiatives to citizens and to keep the decision and implementation process transparent. However, the spirit of e-governance in a smart city should be citizen-centric and citizen-driven. This is one of the missing aspects in most of the initiatives promoted so far and described in section 5.

Table 3 reports the dimensions in which the concept of smart city has been structured by different authors. The review about many of the proposed dimensions of a smart city confirms an interpretation far from the simple use of ICT.

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

1. networked infrastructure need to improve political efficiency and enable social and cultural development;
2. emphasis on business-led urban development and creative activities for the promotion of urban growth;
3. social inclusion of various urban residents and attention to the role of social and relational capital in urban development should be achieved;
4. natural environment is a strategic component for the future.

Table 3. Key dimensions of a smart city.

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4. 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 about where to focus time and resources, as well as to communicate city performance to citizens, visitors, and investors (Berardi, 2013). One of the values of these systems is the capacity to represent a metric of comparison, which overcomes self-proclaims of a smart city. This section aims to report, through a description of existing rating systems, the indicators that are currently assessed in smart city initiatives. However, at the end of this section some notes about the use of these systems for city rankings is reported too.

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 broken out in 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 Smart21 Communities. This metric is based on five factors: broadband connectivity, knowledge workforce, digital inclusion, innovation, and marketing and advocacy. Unfortunately, criteria used for the awards are not known as the Forum has often used its system in a self-declaratory way.

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 to 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 of smart meters and infrastructure sensors; *the open integration layer*, highlighting that smart cities applications should be able to intercommunicate, and share data, content, services, and information; *the application layer*, useful for smart cities to mirror the real-time city operation 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 proposed by Lazaroiu and Roscia (2012). The index was proposed to help the distribution of European funds in the 2020 strategic plan. The indicators which contribute 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 which 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). They used a modified version of the triple helix model, a reference framework for the analysis of knowledge-based innovation systems which 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 innovations, 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).

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

Carli et al. (2013) have recently proposed a framework to analyse and compare measurement systems for smart cities. They suggest dividing the measurement indicators in two categories: objective and subjective, and to consider both physical infrastructures and context data together with citizens' satisfaction and perception of well-being. They 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 socio-economic potential to attract creative people and excellent companies. As stated previously, the University of Vienna has ranked 70 middle size cities according to the metrics defined in Giffinger et al. (2007). Meanwhile, in the Unites States, the Natural Resources Defence 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 world's Smartest Cities. This ranking considers a city that is compact and efficient and provides favourable 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 is 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.

5. Experiences of smart cities

If the multitude of definitions and meanings given to the smart city term shows how difficult is to have a unique interpretation of this concept, the practical experiences reveal even more variegated interpretations. Specific initiatives characterize any experiment of smart city. At the beginning of 2013, there are approximately 143 ongoing or completed self-designated smart city projects (Lee at al., 2014). Among these initiatives, North America (35 projects) and Europe (47 projects) are currently leading efforts, Asian countries are active with around 50 projects, whereas other regions around the world contribute with 11 projects in South America and 10 projects the Middle East and Africa (Lee at al., 2014).

In Canada, the Ottawa's 'Smart Capital' project involves enhancing business, local government and community use of internet resources. Quebec City in Canada was a city highly dependent upon its provincial government because of its weak industry until early 1990s, before then the city government kicked off a public-private partnership to support the growing multimedia sector and high-tech entrepreneurship. In the United States, Riverside has been improving traffic flow and replacing aging water, sewer and electric infrastructure by a tech-based transformation. In San Diego and San Francisco, ICTs have been major factors in shaping and ensuring the success of them as '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, among which Barcelona, Amsterdam, Berlin, Manchester, Edinburgh and Bath. In the UK, 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 a center to economic development for the whole country, harnessing ICTs by fostering high-tech parks. The strong focus on high-tech initiatives has led to reconsider the European actions towards smart cities. Together with the new definitions of term proposed in the last years, the European Commission has introduced smart cities in Line 5, Energy Policy of the Seventh Framework Programme for Research and Technological Development. This Framework Programme provides financial support to facilitate the implementation of a Strategic Energy Technology plan (SET-Plan) which provides several funding schemes related to an initiative called 'Smart cities and communities'. As a consequence of the wide interpretation of these terms, projects with strong social or environmental implications have been promoted in the last years (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 distribute 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 for environmental issues and limited one for 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 crisis has slowed this initiative, which was highly criticizes 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 or Hong Kong are following a similar approach, aiming at promoting economic growth thanks to a smart city evolution. 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's 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 with 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 the present, there are 13 projects in progress towards the smart city initiatives of New Songdo. This project suffers all the contradictions we have pointed in Masdar, and it is not surprisingly 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 neoliberal urban development policies where the construction of a smart city image becomes useful to attract investments, leading sector professional, 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 initiatives 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 extensively literature about these cases in (Cugurullo, 2013, Greenfield, 2013, Liu and Peng, 2013, Halpern et al., 2013,Shwayri, 2013).

Table 5. Examples of initiatives promoted in three smart cities.

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6. Conclusions

This paper attempts to clarify the meaning of a concept that is getting increasingly popular, that of smart city. An in-depth analysis of the literature revealed that the meaning of smart city is multi-faceted. Starting from the original meaning of a city in which ICT play an important role, the definitions of smart city is slowly evolving to include also the dimensions of people and community. 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 the 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 development of self-declaratory metrics for self-labelling as "smart city" lacks universality and generality.

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 pointed the problems of may ranking systems which lead a loss of information on the complexity of a smart city. This study contributed to identify how cities can be considered smart along more than one dimension, by having reviewed definitions of smart cities, its main dimensions, measures of performance and, finally, providing real case examples of smart cities projects. Many aspects remain to study, and how the complexity of the people's request for a better city can be satisfied is still a mystery. However, we hope that this paper will be useful for policy makers to identify smart cities, to plan incentives for their development and to monitor the progresses of cities, towards getting smarter cities.

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Table 1. Definitions of 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 sustainable greener city, competitive and innovative commerce and an increase life quality with a straightforward administration and maintenance system of city	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. (2009)
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 for 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)
(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 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	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 (2011)
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 role 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)
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)
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)
Smart Cities initiative tries 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 amongst different economic actors and to encourage innovative business models in both the private and public sectors.	Marsal-Llacuna et al. (2014)

Table 2. Dimensions of a smart city and related aspects (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

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 living 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)

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, Debt of municipal authority per resident, Median or average disposable annual household income, Unemployment rate, Energy intensity of the economy, Percentage of projects funded by civil society, Employment rate in: High Tech and creative industries - Renewable energy and energy efficiency systems - Financial intermediation and business activities - Culture and entertainment industry - Commercial services - Transport and communication Individual level of internet, Number of local units manufacturing High Tech & ICT products, Companies with headquarters in the city quoted on national stock market, Components of domestic material consumption *smart people*: Percentage of population with secondary-level education, Percentage of population with higher education living, Percentage of inhabitants working in education and in research & development sector, Voter turnout in national and EU parliamentary elections, Share of female city representatives, City representatives per resident, Foreign language skills, Participation in life-long learning, Individual level of computer skills, Patent applications per inhabitant, Employment rate in knowledge-intensive sectors *smart governance*: No. of universities and research centers in the city, No. of courses entirely downloadable from the internet/total no. courses, e-Government on-line availability, Percentage of households with computers, Percentage of households with Internet access at home, e-Government usage by individuals, Number of research grants funded by companies/foundations/ institutes *smart environment*: ambitiousness of CO_2 emission reduction strategy, Extensiveness of city energy efficiency standards for buildings, Total annual energy consumption, Efficient use of electricity, Total annual water consumption, Efficient use of water, Area in green space, Greenhouse gas emission intensity of energy consumption, Policies to contain urban sprawl and to improve environmental performance, Urban population exposure to air pollution by particulate matter, The total percentage of the working population traveling to work on public transport/bicycle/foot, An assessment of the extent to which citizens may participate in environmental decision-making, An assessment of the extensiveness of efforts to increase the use of cleaner transport, Total CO_2 emissions, Percentage of new buildings and renovation which were assessed in terms of sustainability, Percentage of citizens engaged in environmental and sustainability-oriented activity, percentage of total energy derived from renewable sources, Combined heat and power generation, Proportion of recycled waste *smart living*: Percentage of professors and researchers involved in international projects and exchange, Percentage of accessible courses for people with disabilities, Proportion of the area for recreational sports and leisure use, Green space to which the public has access, Number of public libraries, Number of theaters and cinemas, Health care expenditure, Tourist overnight stays in registered accommodation, Total book loans and other media, Museum visits, Theater and cinema attendance, Number of enterprises adopting ISO 14000 standards, Proportion of people undertaking industry based training
Lazaroiu and Roscia (2012)	18	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

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.