Chapter 3

General Features of Smart City Approaches from Information Systems Perspective and Its Challenges

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Abstract

The Smart City (SC) idea has attracted increasing attention due to fast growth of urban centers. SC concepts require more complex and higher quality services for their citizens, most of which are supported by Information and Communication Technologies (ICTs). In order to tackle this emergent topic, different e-government systems and technologies have been used for several urban services, such as mobility, economics, healthcare, education, among others. Such systems can be part of Systems of Systems (SoS), which have an intrinsically challenging developing process due to complex aspects, such as infrastructure issues, data and subsystems integration, and data management in decision support systems (DSS) for all stakeholders. Therefore, the use of innovative technologies must be addressed, and this chapter outlines the general landscape on SC approaches, discussing issues from Information Systems (IS) perspective considering different concepts available in the literature. This work also highlights current and forthcoming challenges for this IS area, including design, implementation and deployment of such systems, as well as a method to evaluate an SC from an IS perspective.

3.1. Introduction

The world is undergoing dramatic change in its demography. The urban population will grow about by 2.3 billion over the next 40 years. By 2050, around 70% of its population will be living in large cities. If this growth does not happen in a systematic way, important issues may arise, such as difficulties related with waste management, resource availability, air pollution, traffic congestion, deteriorating infrastructure, among others. Therefore, better living conditions require a deeper understanding of Smart Cities approaches (SCs) in order to take advantage of available technologies associated with aspects of urban life. Such technologies enable improvements in quality of life in an orderly and sustainable way.

Different cities may require distinctive approaches to SCs, i.e. the Brazilian Network of Human and Smart Cities (RBCIH – *Rede Brasileira de Cidades Inteligentes e Humanas*, in Portuguese), founded in 2015, presents its own requirements [RBCIH 2016], considering the specificities of Brazilian cities. This network initially included eleven cities with their respective institutes of science and technology, joining both government and research groups. Technological aspects are considered by RBCIH to deliver positive impacts on security, health and other city-related services, as well as possible social impacts, i.e. improve quality of life of their citizens. Improvements are mainly related to e-government maturity model, implementation and use of computational tools to allow public transparency and participatory government. In the latter locals take part in the decision-making process regarding solutions for their city, in such a way that citizens and government join a virtuous cycle. Consequently, for Brazilian cities, the main idea is to promote SC initiatives to improve the quality of services provided to its citizens, as well as guarantee their participation in the government decision-making process.

The purpose of this chapter is to present the general features of SCs, highlighting challenges to the Information Systems (IS) perspective. This work provides (i) an overview of concepts and approaches for SCs, as well as IS related technologies and methods (ii) challenges in the area of IS within the scope of the SCs, from creation to implementation and (iii) insights on analyzing the impact of such systems on citizens.

This chapter is organized as follows: Section 3.2 presents concepts related to SCs. Section 3.3 presents a general view of SCs from the IS perspective. Section 3.4 discusses IS challenges that make the implementation of solutions for SCs effective. Section 3.5 describes a method for an ongoing evaluation of how these challenges will evolve. Section 3.6 presents the conclusions of this chapter.

3.2. Theoretical Concepts

3.2.1. SC Approaches

The term "Smart City" firstly emerged in 1997 in the Kyoto Protocol. Concurrently, since 1999 the term "Digital City" has been widely cited in literature due to widespread use of the Internet. However, it was only in 2010 that the term "Smart City" became widespread. According to [Cocchia 2014], a city is a Digital City when it follows digital policies to supply electronic services to citizens using the Web, Cloud Computing and the Internet of Things (IoT); it is a Smart City when it follows sustainable strategies for sustainable and innovative usage of their own natural resources; and it is a Digital-Based Smart City when it follows sustainable strategies using technologies applied to digital cities. In this case, a Digital City is an Information and Communication Technology (ICT) component using a SC strategy. In a broader perspective, Pardo and Taewoo (2011) present the concept of SCs as a combination of different aspects, organized in three dimensions:

i. **Technological**, which considers the use of infrastructure, especially ICT, to transform and improve quality of life and work in a city. This dimension includes the concepts Digital City, Virtual City, and Information and Ubiquitous City.

ii. **Human**, which considers people, education, learning and knowledge, since they are key factors to turn a city smart. This dimension includes concepts of Learning City and Knowledge City.

iii. **Institutional**, which takes into account governance and politics. Cooperation between stakeholders and institutional government is very important to design and implement SCs initiatives. This dimension aggregates concepts of Intelligent Community, Sustainable City and Green City.

On the other hand, [Lee et al. 2013] and [Dameri and Rosenthal-Sabroux 2014a] present the SC concept based on six main dimensions: Smart Economy, Smart Mobility, Smart Environment, Smart People, Smart Life and Smart Governance. Alternatively, Giffinger and Gudrun (2010) states that: "a city is smart when their investments in human and social capital, in urban transport and ICT infrastructure allow a sustainable economic development and a better life quality, with a wise management of natural resources, throughout a participatory governance". Thus, projects in SCs should have overlaps among these dimensions. For instance, a new public transport system based on low carbon emissions leading to positive impacts on mobility as well as a sustainable use of the environment.

Cocchia (2014) describes SCs from a different perspective, considering the following core components:

i. **Land**, meaning the geographical area in which the city is located;

ii. **Infrastructure**, meaning a large element including all physical components and materials of a city – buildings, streets, transport facilities, and so on;

iii. **People**, including all citizens, not only residents, but also those who work, study or tourists; and

iv. **Government**, meaning politicians who have the power to govern the city.

The following characteristics enable these components to become smarter [Dameri 2012]:

- **Effectiveness**, related to the ability of the city to effectively meet public and private services for different groups (citizens, companies and non-profit organizations) and for different categories of citizens (students, workers, elderly people). The subjective role of each stakeholder in a smart definition should be included, i.e. a city is not smart by itself, but only when its initiatives create public value to its citizens.
- **Environmental considerations**, related to the ability to measure impact of city growth in environmental quality in urban areas. One of the main pillars of SCs is to prevent even greater environmental degradation. The main impacts are related to energy consumption, water and air pollution, traffic congestion and land consumption. Thus, a SC acts to reduce these aspects to preserve the quality of the environment.
- **Innovation**, which indicates that a SC should make use of all the latest technologies to improve the quality of its main components, to deliver better services and reduce

environmental impacts. Therefore, technology is a central aspect of SC, used in initiatives for improving the life quality in the city.

A smarter land means cleansing the land, air and water as well as reducing land consumption for new construction, environmental recovery, among others. Smarter infrastructure means serving citizens in a more effective way, responding to their needs. In addition, SCs should make use of cutting-edge technologies, ICT and mobile devices to provide electronic services and information. Smarter people mean that citizens are more aware of city goals and rules when using city technologies, improving urban land quality, infrastructure and services. It also means an easier way to access the Internet and mobile devices, and a wider digital inclusion of people. A smarter government uses ICT and available technologies to implement electronic government and democracy in order to improve the quality and accessibility of public services and make citizens more satisfied with local administration.

A common aspect in these approaches is organizing the concepts in different dimensions to construct a framework for SCs. Brazilian cities differ in size and number of citizens in terms of both financial and technological access. Therefore, building a framework specifically for Brazilian cities, can also define strategies for larger countries with similar Brazilian characteristics, such as India, USA, Russia and China. However, each city may require distinctive solutions, considering the prioritization of municipal issues, defined by its local strategic plan. Furthermore, the definition of targets and indicators can enable citizens to assess the public value of applied initiatives, guiding both ongoing and future strategies to make a city smarter. Measuring public value should be the ultimate goal of a SC, which requires that projects and initiatives should at least be indicated by citizens. However, public value is a complex concept, because it includes the definition of values of different types [Dameri and Rosenthal-Sabroux 2014b]:

- Social and economic values, which are difficult to reconcile, and sometimes may be opposed to each other;
- For different stakeholders, who have different expectations that are not always compatible;
- Regarding different dimensions of life cycle, requiring comprehension of the real needs and priorities of citizens.

A framework for transparency proposed by Leite and Cappelli (2010) deploy such aspects, allowing a virtuous circle of understanding between government actions and population issues. Further discussions are present in the following section.

3.2.2. Open Data, Public Transparency and Maturity Model for SCs

Transparency in the public sector is a vital factor in strengthening relations between government and citizens [OECD 1961]. After an extensive review of the transparency concept, Leite and Cappelli (2010) define transparency using the following characteristics:

a. Complete information: all information must be available without restriction;
b. Objective information: the information directly responds to questions asked;

c. Reliable and quality information: information is correct, fair, consistent and accurate;
d. Easy access to information: the mechanism used to access information has a proper response time and proper functionality;
e. Information understanding: the information does not generate doubts. Everyone can understand it;
f. Communication channels totally open: free and easy access to information.

The first step to ensure transparency is to allow access to government data, following a worldwide effort in this regard. In September 2011, the Open Government Partnership (OGP) was launched, an international initiative that aims to encourage government practices globally, such as budget transparency, public access to information and social participation. Therefore, open government data should be legally consistent with the following [Eaves 2009]:

a. If data cannot be found and indexed on the Web, it does not exist;
b. If data is not open and available in machine readable format, it cannot be reused; and
c. If any legal provision does not allow replication, the data is not useful.

Terán, Kashina and Meier (2016) propose a maturity model for Cognitive Cities. The authors emphasize the importance of interaction between government and citizens, and present an e-government framework (e-gov) to ensure electronic empowerment by the population. According to the authors, first level of a maturity model for e-government of a SC is characterized by e-Information, i.e. there is a top-down one-way channel to provide relevant information to citizens about public policies, projects and news, among others. Examples of cities at this level are those with web portals in their municipalities.

Second level is characterized by the e-Consultation, i.e. there is an electronic two-way channel, giving authorities the ability to collect the opinions and comments of the population. Examples of cities at this level are those that perform electronic polls, in which the local government (prefecture) aims to collect citizens' opinions through questionnaires. The third level is characterized by the e-Talk, i.e. there are discussion channels between citizens and governments, and virtual communities are created. These channels enable public projects, ideas and plans to be discussed and commented on. As the process takes place virtually, there is the advantage of a possible participation of specialized groups, which can promote the process of opinion formation. At this stage, citizens are able to establish channels of communication, but neither participation nor decision-making is present. The fourth level is characterized by e-Participation, i.e. there is a two-way channel in which citizens can collaborate in decision making on public projects yet to be developed. At this stage, citizens can establish a greater communication, which includes features such as working in collaboration to increase participation. The first steps for empowerment are made at this stage.

The following applications are considered collaborative elements: e-mail, instant messaging, application sharing, video conferencing, workspace, management of collaborative document and version control, task and workflow management, Wiki groups (or community effort to edit Wiki pages) and blogging systems. Fifth and final level is characterized by the e-

Empowerment, in which there is also a two-way channel. Specifically in this stage, the final decision is in the power of citizens. Local government must implement what citizens decide. At this stage, citizens have the power as channels of communication are much broader and include new and enhanced capabilities for empowerment of the population.

These two frameworks, proposed by [Leite and Cappelli 2010] and [Terán, Kashina and Meier, 2016] for transparency and participation, are interesting in SCs. However, implementing (one of) them should consider a process that includes many changes in culture and philosophical aspects in cities, beyond ISs to enable these initiatives.

3.2.3. Computer Systems Architectures for SCs

According to Mulligan and Olsson (2013), most services in SCs are based on a centralized architecture, in which a dense and heterogeneous set of peripheral devices installed in urban areas generate different types of data. Such data is made available by appropriate communication technologies to a control center where data storage and information processing are performed. However, significant obstacles must be overcome for the successful deployment and implementation of business models, designed for applications and services of SCs. Most of these obstacles are related to an ongoing battle between two main system architecture schools of thought, ICT and Telecommunications for data management and service creation.

SC services tend to use components from both ICT and Telecommunications, and do not benefit from the current binary view of system architecture. For the development of SCs, business models have suggested a strategic long-term vision of evolution of this architecture. Architectural aspects are central in solutions of IoT in the SC context. A primary characteristic of an urban infrastructure for the Internet of Things (IoT) is its ability to integrate different technologies with existing communications infrastructure, to allow a progressive evolution of IoT, interconnecting other devices and implementing new features and services. Another key aspect is the need to make (part of) collected data by urban IoT easily accessible by authorities and citizens in order to improve the responsiveness of the authorities to city problems, and to promote awareness and participation of citizens in public matters.

Mulligan and Olsson (2013) discuss the evolution of an architecture to ensure more effective implementation and deployment of technologies for SCs. There are many standards for IoT struggling to become referential and most adopted by the community. However, as it is open and royalties-free, IETF (Internet Engineering Task Force) standards have been considered in first place. Zanella et al. (2014) propose a web service based architecture for urban IoT. However, a larger work for implementation and evaluation of the effectiveness of such architectures in cities remains a challenge for Brazilian cities.

3.3. A general landscape for SCs from IS Perspective

This work establishes four layers considering a general landscape including diverse SC approaches from the IS perspective. Figure 3.1 depicts these four layers. The **first layer** is the physical infrastructure that provides ICT services, including the Internet of Things (IoT) and technologies for collecting and providing Open Data. The **second layer** provides IS that must be implemented to support services to the citizens. These ISs may be (i) systems regarding to only one domain, such as a system for healthcare or education domain or (ii) complex systems, such as SoS integrating data and other systems from the first layer, and using technologies and methods from Collective Intelligence, Big Data, Artificial Intelligence, and other areas. To improve services to the citizens, it is important to provide Smart Governance, preferentially based on some Electronic Government Maturity Model, as seen in Section 3.2.2. Thus, the **third layer** is this Smart Governance, providing mechanisms to allow participation of citizens in local (city) government. These three layers may lead to smarter dimensions in cities, shown in the **fourth layer**. The general landscape is presented considering an instantiation of SC definition proposed by [Giffinger and Gudrun 2010], consisting of six dimensions, i.e., Smart Governance, Smart Mobility, Smart Economy, Smart Life, Smart People and Smart Environment. In this specific point of view, Smart Governance should not only include a government maturity model (present in the third layer) but also IT governance methodologies in all government sections. This should be considered from the first layer. It is worth noting that the fourth layer should be divided into other dimensions of interest for an adopted SC concept.

3.4. Challenges for IS in this General Landscape

3.4.1. Developing SoS for SCs

Implementing systems to meet demands of a SC is highly linked to the SoS approach (SoS), which emerged in the last decade. A system is a set of elements (or subsystems) that interact and bind themselves through an internal structure. This system concept is already universally accepted, but the definition of SoS depends on its application domain and its focus. Dersin and Transport (2014) present a survey of various SoS features. This work presents two of them that show how systems for SCs can be encompassed in the SoS approach:

- Autonomy, coherence, permanence and organization of the (sub)systems
- SoS is a complex system composed of many constituents that interact in a network structure. These constituents are often physically and functionally heterogeneous, and organized into a hierarchy of subsystems that contribute to the function of the overall system, which leads to structural and dynamic complexity. The structural complexity implies i) the heterogeneity of the constituents in different technology fields due to increased integration between systems and ii) an increase in the range and dimensionality of connectivity across a large number of constituents (nodes) which are highly interconnected by dependencies and interdependencies. The dynamic complexity implies that the system sometimes behaves unexpectedly in response to changes in environmental conditions and the operation of its constituents. Emergent behaviors can be positive or negative as they can lead to unexpected consequences. Additionally, uncertainty can be generalized in complex systems, and its quantification and propagation are fundamental aspects in the prediction and control of such systems.

  There are four other properties, known as "Maier's criteria" [Maier 1998]:

- Operational independence, i.e. each system is independent and should achieve its goals by itself;

- Management independence, i.e. each system is managed largely for its own ends, instead of considering the effects of the SoS;
- Geographical distribution, i.e. a SoS is distributed over a large geographical area, or its constituents can communicate among themselves through some network technology;
- Evolutionary development, i.e. a SoS evolves with time and experience.

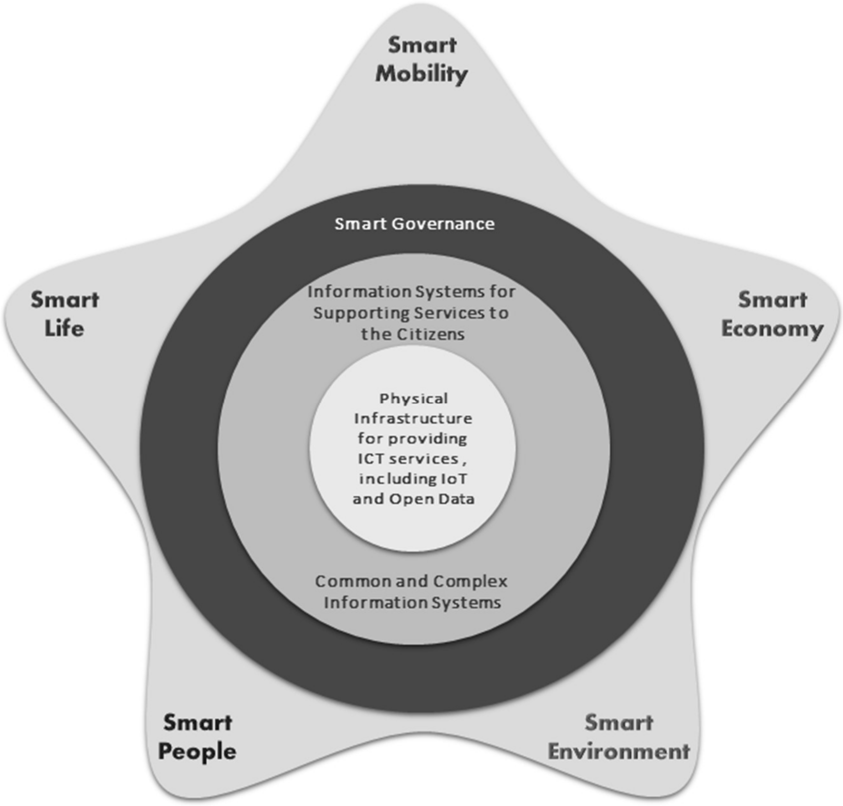

Figure 3.1 – A general landscape of SC approaches from IS perspective, considering four layers. The dimensions to be considered in a SC in the fourth layer may vary according to city stakeholders

With regard to IS, a major challenge today is to ensure that all SC systems get results considering the integration of subsystems. Over the next 10 years, an important challenge is to define models, methods and tools to support the development of SoS that allow integration of data and services from different organizations, according to the four layers and dimensions illustrated in Figure 3.1. Other challenges related to SoS development as a wider and effective SC solution are: (i) defining and ensuring the availability of useful open data for both citizens and managers of cities (ii) designing and developing systems and applications to visualize and make data available for all citizens (iii) building models, methods and tools to process and display unstructured and semi-structured data sources and (iv) defining evaluation indicators of systems that provide services to citizens.

3.4.2. Information Interoperability to support Public Transparency in SC

Several Brazilian government agencies already publish their data on the web through reports and balances so that citizens can monitor the results of government actions [Breitman et al. 2012]. This move in recent years to implement e-government and Open Data solutions in

Brazilian government levels also serves as a framework for the concept of SCs because a participatory and transparent government can only be guaranteed based on these principles. In an open data solution, all information must be classified as open, secret or ultra-secret. If information is classified as secret or ultra-secret, mechanisms for ensuring digital security must be adopted. If it is open, there is a federal effort to make this kind of information available to the public.

It is also important to adopt data formats that ensure information interoperability, such as those from the Semantic Web. In many cities, there is a lack of integration between municipal departments and the central administration. Some departments implement different access policies, while others do not share information. Initiatives aimed at integrating and/or generating data to support decision making in different municipal sectors are a challenge for the IS area, as these different areas of knowledge have their own vocabularies. Moreover, general data sources are not tailored to allow information interoperability, e.g. following Semantic Web precepts [Hepp et al. 2008].

Open data for citizens is only the first part of a SC adoption. There are many more challenges for constructing and implementing a maturity model for Brazilian cities that involves not only public transparency, as the one proposed by Terán, Kashina and Meier (2016), that provides open data and government processes in cities, but also considers other aspects of SC. One initiative is in development by RBCIH [Pereira, 2017], however, more efforts should be invested here. Last but not least important, concise and interpretable information for citizens are important factors for transparency.

3.4.3. Big Data Processing for Decision Support in SC

Urban computing is an interdisciplinary field which studies urban issues using computer technologies [Silva and Loureiro 2016]. A SC context expects that systems from distinct fields providing many solutions are interconnected: computer systems that provide data, information and knowledge are open to the public, sensor networks, networks of objects are connected to the Internet of Things (IoT), and smart grid electricity, among others. Such systems generate data in various formats – structured data, such as the one stored in relational database systems; semi-structured data, such as data available in data formats attached as RDF triples (Resource Description Framework), JSON and XML format; or unstructured data, such as data collected from sensors, climate information data collected from cameras, image format, or as text, such as comments on social networks about the quality of services in cities.

This huge amount of data needs to be collected, stored and treated. It requires techniques and methods based on machine learning, data analysis and visualization for integration and selection of this huge amount of data. Some initiatives for evaluating data visualization techniques are in progress based on the user profile, as can be seen in [Barcelos et al. 2017]. However, recommending appropriate visualization according to user profile remains a challenge, as there are many user variables to guide this recommendation. Furthermore, there are many different approaches to handling, processing and extracting useful knowledge from such data, coming from Data Science area. In addition, tools to automate these processes in cities are required. Therefore, a challenge in this context is to develop frameworks to accommodate these various solutions to improve efficiency and sustainability for citizens, by providing additional features and allowing a dynamic reconfiguration of the city data environment. These tools should support decision making without requiring knowledge about data mining and big data areas from final users. They must also consider different user profiles, such as people and government, and privacy issues when appropriate.

Pérez-González and Diaz-Diaz (2015) describe an approach where various services are offered in 26 SCs in Spain, reducing administrative costs in sectors that have implemented such services. A business model for implementing SCs concept is required [Diaz 2015], because the amount of generated data may be a source of income for cities since it can aggregate valuable information in new software as solutions to citizens. Computing colleges and business forums in Brazil generally discuss largely the implementation of SC concepts based on Digital City. However, issues related to data integration, cognitive computing, big data, ontologies, implementation and business models for systems development, among others, are still not considered the implementation of SCs usually requires a big financial investment. Building sustainable deployment models are still a challenge.

Comparing cities to understand the relationships among them is one important and interesting issue in SCs. Giffinger and Gudrun (2010) rank European medium size cities. However, comparing heterogeneous cities, such as ones in large countries, such as Brazil, India, USA and others, may be very difficult. So, one challenge is related to grouping cities according to different profile indicators, considering each specific context. Some initiatives based on clustering techniques have been proposed in literature, such as [Barcelos et al. 2017] and [Afonso et al. 2015]. However, there are challenges related to the impact of ranking when the cities were previously grouped, in many different contexts.

3.5. Progressive evaluation

This work proposes the use of the four layers presented in Section 3.3 to assess not only the level of development of a SC from the IS point of view, but also the level of evolution in challenges for SCs solutions from the IS perspective. ICT infrastructure is primary for collecting data and integrating systems. Thus, an SC from an IS perspective is at level 1 if it has a large infrastructure for supporting services to population. A SC is at level 2 if, beyond level 1, if it provides open data and other isolated IS for services, not considering their integration yet. A SC is at level 3 if, beyond level 2, it implements System of Systems (SoS) that integrate the systems and use technologies and methods from diverse computing areas, such as Collective Intelligence, Big Data, Cloud Computing, Ambient Intelligence and others, for improving quality of services to the citizens. A city at this level also provides transparency in its governmental processes. A SC is at level 4 if, beyond level 3, it provides mechanisms for guaranteeing citizen e-participation, where IS should be widely used. Furthermore, a city at this level has mechanisms available to evaluate the impact of smart initiatives for their citizens. Methods for evaluating the degree of transparency and integration of data and systems (in SoS perspective) should also be used in this case.

3.6. Conclusions

This chapter presents a general landscape on SC from the IS perspective, and some challenges related to developing IS in the SC context for the next 10 years. A scheme containing four layers was established to demonstrate the aspects that must be considered when implementing a framework of SCs into a city. The first one is related to ICT and IoT infrastructure; the second layer is related to IS to integrate data and constituent systems; the third layer is related to smart governance, including transparency issues; and the fourth layer is related to services to citizens.

The challenges, presented from the IS perspective, include research in city context related to SoS, open data and transparency, information interoperability and big data processing to support decisions. It should be noted that many of these challenges can be handled separately. However, cities offer an arena in which these challenges may appear together, causing interference among areas. For instance, integrating systems through SoS architecture may hinder transparency, as specifications for defining information classification as secure or open may lead to inconsistencies in the integration process.

These challenges involve many computing research areas, such as Software Engineering; Human-Computer Interaction; Artificial Intelligence; and Database, Information Visualization, Big Data and Data Mining. Technological development involving other knowledge areas may also occur, due to the interdisciplinary nature of a SC project. Social scientists, architects, health and mobility experts, engineers and others should be involved in tackling these challenges. Moreover, there is a large overlap among SCs challenges and challenges for Computing, listed in [Salgado, Motta and Santoro 2014]. "Data Science", "Mobility" and "Health" are examples of this intersection, particularly important given the difficulty of collecting and processing large volumes of commonly heterogeneous data.

Finally, we argue that in order to evaluate evolution in all these challenges and thus categorize a smart city in maturity levels, the following aspects should be assessed: (i) availability of IT infrastructure for supporting services to population (ii) provision of open data and other e-services (iii)integration among IS systems and the e-services provided by them, enhanced by the adoption of technologies such as Collective Intelligence, Big Data, Cloud Computing and Ambient Intelligence; and (iv) provision of mechanisms for guaranteeing citizens e-participation, and for evaluating the impact of smart initiatives for their citizens.

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