Smart City Concept: What It Is and What It Should Be

Iker Zubizarreta[1]; Alessandro Seravalli[2]; and Saioa Arrizabalaga, Ph.D.[3]

Abstract: The *smart city* concept is often simply considered equivalent only to technology. This paper starts by introducing the necessity of a holistic, integrated, and multidisciplinary approach to the concept of smart cities. Smart cities are evolving by the creation of tools that are application specific; therefore, European classification of smart city applications will be reviewed (as authors have used these criteria to classify the analyzed applications) and the relationship between the different European smart classification standards are analyzed. Moreover, in order to see how reality aligns with the theoretical concept of smart cities, the authors analyzed 61 applications from 33 smart cities distributed in North America, South America, Europe and Asia. From these, 16 specific applications from eight cities have been selected and described in detail so they provide an overview of existing tools in different application areas, as defined by European standards. After showing actual smart cities, the concepts and steps for building future smart cities are suggested in a conclusion. **DOI: 10.1061/(ASCE)UP.1943-5444.0000282.**

Author keywords: Regional analysis; Case studies; Classification; Asia; North America; South America; Europe; Urban areas; Planning; Communication.

Introduction

Many smart city projects are territorial marketing projects and in most of the cases the actual status of implementation or their impact on the launch of the city is not known (EC 2011). Investigating the interconnection between the different areas and analyses of the city requires a more holistic, integrated, and multidisciplinary approach. The widespread and rapid evolution of information and communication technologies (ICT) provides tools that may support this approach, or can be used as tools (Taylor and Johonston 1995) to improve the efficient of the city system.

By recovering the sense of citizenship, the purpose of smart cities can be better understood, so that a *smart city* represents a mode of life, an ideal city to develop and rediscover (Yuan and Li 2014). In this sense, sustainability involves the smart concept, less waste, better quality of life, better social life, andgreater efficiency. Apart from the improved energy efficiency, a smart city requires much more than an energy or mobility system, it also implies an adoption of a remote monitoring and control system. The keyword for a smart city is *communication* (Roche et al. 2013), including intercommunication of energy, resources, information systems, and between monitoring equipment and control of services and participation. A smart city is something that is constantly evolving and therefore requires constant communication and dissemination of information.

If communication is the smart city keyword, it is obvious that the city needs to communicate with the outside world. In this sense, the enhancement requires the active involvement and participation of various communities. The development of the city (and therefore also the growth or the management thereof) must be based on a smart program. The planning itself is an essential element for development, but it is often an anachronistic and monolithic plaster.

The smart city concept is not just an application; it is an infrastructure of information and an application system for the city (McFedries 2014). There are a lot of correlations between urban planning and the development of cities with energy consumption or telecommunication networks. As more people live in a district or neighborhood, an improved energy and communications network is required. In-depth knowledge of the telecommunication and energy network is essential to understand and make decisions about city development.

Why are there cities? Cities are a human invention; they were born from the human need for security, the convenience of living together, easier management of resources, better quality of life, smaller mobility distances, etc. With smart cities people can reinforce their role and their proximity inside the city space. They have become the actual modality for the governance of cities (smart method, smart approach, smart development, and smart applications, but also in the fusion of languages, overlay of information, and overlay of systems). This governance implies a territorial and geographical approach (Norman et al. 2006; Doherty et al. 2010). If once the core of the city was the square (from agora in the Greek time to the polycentric city in the modern age), today it is a continuously connected place: if all is the center, nothing is the center and it is possible to recover the role and form of the city public spaces. Smart cities pose a concrete challenge for the future of cities (Staley and Claeys 2005). The city will be the place that will enable societies to solve the economic and social crises of recent years (Li and Liu 2013). In the coming years, the majority of the world population will live in cities. In the face of this both historical and new event, working on joining the smart cities concept means combining the tool with the end; the significance of this process then leads to the smart city becoming an icon.

The citizen is the protagonist of the city, belonging to the site and therefore the place is something that concerns him. Without this complicity there can be no real active citizenship participation, and consequently it cannot be a real intelligent city. It is necessary

[1]Sis.Ter s.r.l., Via Mentana 10, 40026, Imola (Bo), Italy (corresponding author). E-mail: iker.zubizarreta@orangemail.es

[2]Sis.Ter s.r.l., Via Mentana 10, 40026, Imola (Bo), Italy. E-mail: a.seravalli@sis-ter.it

[3]CEIT and Tecnun, Univ. of Navarra, Electronic and Communication Dept., Paseo de Lardizábal 15, 20018 San Sebastián, Spain. E-mail: sarrizabalaga@ceit.es

Note. This manuscript was submitted on September 3, 2014; approved on March 16, 2015; published online on May 18, 2015. Discussion period open until October 18, 2015; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Urban Planning and Development***, © ASCE, ISSN 0733-9488/04015005(8)/$25.00.

to go deeper, to understand the relationships and phenomena that take place in the city. Without this active role of the citizen, real smart cities cannot exist.

In such a changeable system, the active and conscious role of the citizens will be increasingly important. The map then becomes a tool of awareness, representation, expression, communication, as well as management, governance, and planning. Due to the Internet, the definition of spatial dimension has changed. The virtual square becomes a replacement of the physical square. The smart city is the challenge that aims to approximate the real world and the virtual world, the world of those who govern with the people, all in accordance with a sustainable approach. As Borges (1949) wrote, "You see a set that is multiple without disorder; see a city."

Much research has been done to analyze in detail different applications and services. From a single application point of view, that of transportation is frequently highlighted in the American (Johnson and White 2010) and European examples (Russo and Comi 2011).

In contrast, this paper presents a multidisciplinary analysis of smart cities, identifying applications from different areas and also studying the level of integration among them. In order to better understand how smart cities are evolving, the authors saw it necessary to condiuct a detailed analysis of actual existing smart cities all over the world and to study their characteristics. In this paper, the results of the analysis of 61 applications from 33 smart cities are shown, distributed in North America, South America, Europe, and Asia.

In the next section, the European classification on smart city applications will be reviewed (they are the criteria authors used to classify the analyzed applications) and the relationship between the different European smart classification standards is explained. Next, the details of analyzed applications are offered; moreover, two applications from eight cities (from Europe, North America, South America, and Asia) are described as examples. An analysis of the examples is also carried out and finally conclusions are presented.

Classification of Smart City Applications

First, the European smart city classification standard are introduced, and the topics of economy, people, living, governance, environment, and mobility are explained. The relationship between the different areas will then be analyzed in detail.

European Smart City Classification Standard

This section aims to clarify the European smart cities classification standards, explaining the importance of each one, and analyzing the correlation between them. The European standards use six key points for smart cities classification: economy, people, living, governance, environment, and mobility (Giffinger et al. 2007). These topics, and the correct management and interaction between the different applications used to develop these standards, add value to a city becoming smarter, and show the real state of the development of the city or region.

These six working areas are focused on solving the main problems of actual cities, and attempt to avoid the new issues that will come, like macropopulation-related problems, mobility and environmental issues, or energy savings. Citizen participation and governance transparency are the other topics in smart city development.

Each application should not be totally focused on just one classification standard, but each of them should contribute to the development of at least one of these topics, and should never react in a negative way to any of the classification points. For example, an application that offers a large economic profit but causes large environmental problems could never be classified as a smart application. The same would happen to an application that adds value to the environmental side but hampers the economic growth rate.

Economy (Competitiveness)

The following are the key factors involved in the *economy* classification: innovative spirit, entrepreneurship, economic image and trademarks, productivity, flexibility of labor market, and international embeddedness. The only way of carrying a powerful economy, with sustainable and social growth, is to innovate by opening new fields of business, adding new technologies to the manufacturing chains so the productivity increases and the cost and environmental impact decrease. To be able to apply these initiatives, big investments are usually needed, which can only be supported by strong economies.

All the other smart cities characteristics are dependent on this one: without a positive economic situation, it would be impossible to apply most of the applications in the European standard classifications. All the applications should react in a positive way to the economy of the site: this does not mean that the application should be planned as a business but as a tool for economic growth and as a window for new development opportunities.

People (Social and Human Capital)

The following are the key factors comprising the *people* classification: level of qualification, affinity to lifelong learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism, open-mindedness, and participation in public life.

The participation of the citizens in the public life of the city and the smart behavior of citizens are the main points of this classification standard. To encourage smart behavior and an active public participation of citizens, a creative and multicultural background is needed for a more complete knowledge of public life and an ability to cooperate on daily issues in the city with an open mind.

The vision of the city that a citizen can share is one of the best types of information that any government can obtain, being informed of the real cares of the citizen and the deficiencies of each neighborhood in a near and more personal way, and in real time. This large amount of data must be carefully analyzed and priorities identified. In that way, the main issues of the city are solved faster and better, while supplying information focused on the key development factors of the city.

Living (Quality of Life of Citizens)

The following are key factors involved in the *living* classification: cultural facilities, health conditions, individual safety, housing quality, education facilities, touristic attractiveness, and social cohesion.

This characteristic is related to the life of the citizens, the social advantages they can apply, and about the public healthcare, security, and educative systems. One of the main objectives of a smart city is to offer a better quality of life, a better information system for citizens, and a more comfortable living. This is achieved by adding new technologies and management systems to the existing services to improve them, and by including new services for a more comfortable and sustainable living.

Governance (Participation of Citizens)

The following are key factors comprising the *governance* classification: participation in decision making, public and social services, transparent governance, political strategies, and perspectives.

This classification refers to the way that the government acts, and the degree of transparency and usefulness in the management of public sources. Usually online platforms are used for encouraging the citizen to participate in public life; one of the most used platforms is the report site, where a citizen can report any issue. Other sites include opinion portals where the government can ask directly for the public's opinion about one project or idea directly; this kind of project is like an online referendum.

Environment (Natural Resources, Sustainable Growing)

The following are key factors that for the *environment* classification: attractiveness of natural conditions, pollution reduction, environmental protection, and sustainable resource management.

One of the biggest current global cares is the environment: cities and industrial areas, usually are located in the city suburbs, are the biggest pollution sources. As the population grows, the pollution grows. Solving the pollution problems in cities and the reduction of energy consumption are key for a more environmentally friendly living. One of the most important points is the correct management of tnatural resources; more concretely, the biggest efforts are being made involve public utilities (i.e., electricity, water, and gas management). The CO_2 emission reduction is a main priority, including the creation of green spaces.

Mobility (Transport and ICT)

The following are key factors comprising the *mobility* classification: local accessibility; international accessibility; availability of ICT infrastructure; and sustainable, innovative, and safe transport systems.

As the population of cities has grown exponentially and seems to keep growing, one of the biggest problems actually and in the future will be mobility (Nadeem 2011). Mobility also contributes a big percentage of the pollution of cities, and the usual retentions and congestion problems lead to a high economic cost and higher levels of pollution (Ceder 2004). The quality and frequency of public transport and the amount of people that use it are keys for mobility in the future, reducing the number of single riders as much as possible and promoting the use of sustainable vehicles like the E-bikes and E-cars (Midgley 2009).

Relationship between the Different European Smart Classification Standards

All the European classification standards have a close relationship between them; it is impossible to develop one without influencing any of the other characteristics. Therefore, this section describes the main relationships between the classifications given. All the characteristics are dependent on the economic one. The economic capacity of the specific application must be realistic; development of the smart application must lead to economic growth, adding new business opportunities and giving economic value to underused resources. For example, energy consumption savings are usually classified as environmental applications, but they have a direct relationship with economic savings.

Nearly all the environment applications are focused on energy and resource savings, waste recycling, and the inclusion of efficient public transport and environmentally friendly mobility options for citizens, like electric vehicles. The relationship between the environmental applications and the economic and mobility development characteristics is clear: a more environmentally friendly city also means a better living for citizens, with less health issues and more pleasant daily living.

The main mobility applications are focused on public transport systems, like bike share programs, electric cars, and electric bikes as transport alternatives for citizens (Delucchi and Kurani 2014). All these applications are closely related to the environment topic, specifically to energy savings and thus economic savings. These applications enable a more comfortable living with a cleaner and faster mobility for citizens. The development of an application usually is not limited to one purpose: nearly all the applications that affect the citizens' life have other main objectives like the environment, mobility, or economic growth, and also impacts a better life.

The governance and people characteristics represent two sides of the same coin. On the one hand, there are the governance applications that are used to keep the citizens informed, to manage more efficiently the city sources, and to offer a more transparent and participative governance. On the other hand, there are the people standard developments: these applications encourage citizens to participate in the political and public life of the city, adding new responsibilities to the citizen for a more smart behavior, and thus being able to apply smart applications in a correct way, with the participation and correct use of the citizens. Both characteristics are interrelated: smart government would not be possible without the participation and interest of the citizens, and the concept of smart people would not make any sense without a government that gives to its citizens the chance to participate in the daily life of the city, or without an educative system that creates social and cultural knowledge for useful participation and cooperation of the citizens. Both characteristics are closely related to the living one, creating a new way of governing a city, and a smart and open-minded behavior of the citizens, developing a bidirectional synergy between government and citizens.

As discussed, it is impossible to develop one concrete application focusing only on one smart city characteristic. All the characteristics should be linked and act as one, as the smart city is a mix of technological applications that are interconnected with a common purpose. The correct use of the system of applications will lead to success in a real smart city.

Examples of Current Smart Applications

For this overview of applications, 61 applications from 33 different cities have been analyzed. Table 1 presents an exhaustive list of the analyzed applications and locations. The level of integration between the applications in each analyzed city has already been highlighted. The cities are from North America, South America, Europe, and Asia; the percentages of the distribution are shown in Fig. 1.

The most applications are found in Europe, followed by North America (Fig. 2). In South America, there has been an increase in interest smart topics in recent years, especially focused on mobility and the environment. The lowest percentage of area-specific applications has been found in Asia, where some examples of Smart applications were discovered, concentrated in developed megacities like Singapore and Tokyo.

For this overview on the various smart city area-specific applications, two different cities have been chosen for Asia, Europe, North America, and South America, taking into account the current situation of the smart city development, and in relation with the

Table 1. Exhaustive List of the Analyzed Smart City Applications

City	Integration level	Applications
		South America
Rio de Janeiro	N	Integrated operations center
		Digital map of hot spots
Curitiba	L	Bus rapid transit
		Green spaces
Medellin	L	Metrocable
Santiago	N	Control center to monitor traffic in real time
		Bike sharing and E-car sharing program
Mexico City	N	Buildings that absorb nearby smog
		Analysis of open data initiatives
		Bike sharing program and e-car share program
Bogota	M	Bogota's bus rapid transit system
		Electric taxi fleet
		Electric automated underground metro system
Buenos Aires	N	Ministry of modernization
		Expansive public wi-fi network
		BRT system
Bouzios	L	Smart grid
		Figure of load aggregator
		Electric vehicle and energy charging points
		Integration of renewable energy
		North America
New York	M	Social media channels
		Public administration open data
		Do not eat application
Chicago	L	Advanced digital surveillance system
Ontario	N	Smart meters
Edmonton	L	Analytics center of excellence for road safety
		Social media channel
		Traffic report and requests on Edmonton web
		Open data on the web of Edmonton
		ETS smart bus
		Smart roads
Oklahoma	N	Smart meters
Norman	N	Smart meters
North Carolina	N	University of North Carolina unified multiple data sources in a data warehouse solution
New Jersey	L	Saint Michael's Medical Center automatic tracking systems to eliminate inefficiency
Pittsburgh	N	University of Pittsburgh Medical Center developed a smart room
Nashville	N	Data mining software that analyzes multivariable patient treatment information
		Asia
Singapore	M	Live Singapore project
Beijing	N	Chronic disease management smart process
Tokyo	L	Highway maintenance management system
		Location-aware information services
		E-card: lifestyle consultation (energy saving)
		Smart metering (gas, water, electricity)
		Europe
Lyon	M	Sensed public lighting
Vitoria	N	System to detect leaks and leaks prelocations
		Citizen Bustia
Ceuta	N	250 camera surveillance analyzed in real time
Edinburg	L	Web services pilot
		Town hall multichannel (web, TV, Internet and mobile phone channel)
		Smart cards
London	M	London database
Malaga	N	Variable weather forecast systems
		Aeolian lights
Friedrichshafen	N	GlucoTel telemedicine system
		DerBUTLER mobile system (emergency calls)
Bologna	N	Pedigree analytics platform that integrates genomic data, medical images and family history
Roma	N	WikiCity project
Antwerp	N	New information management smart solution for the Antwerp hospital network
Extremadura	N	Healthcare information management system
Aarhus	L	Aakhotspot (SmartAarhus)
		Clean and tasty drinking water

Note: N = none; L = low integration; M = medium integration; H = high integration.

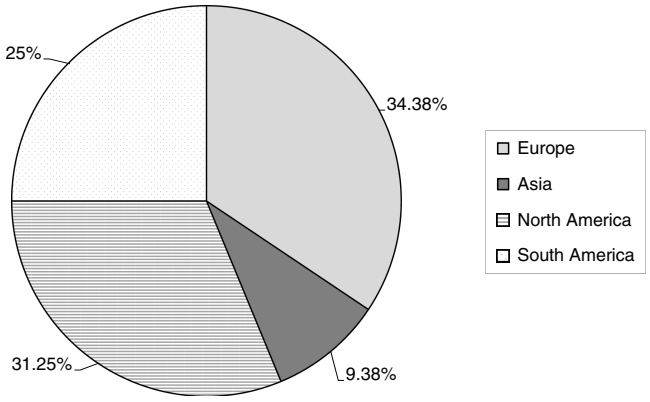

Fig. 1. Percentage of the number of cities analyzed from the total number of cities

future plans that are being initiated in each of the cities (Naphade et al. 2011). Africa has been excluded from this report because the development of the smart city applications has not yet begun.

From the 61 different applications analyzed, it can be observed that apart from the *people* application, which has the lowest percentage, the percentage of applications for each of the areas is quite similar. The percentage of applications of each European standard classification is shown in Fig. 3.

Of the total, eight cities and two applications for each have been selected to be described in detail, trying to select the most representative examples. All the European classification standards have been covered by including applications that have been already deployed in the cities.

It is possible, though, that other cities have the same type of applications, or that the chosen cities have other applications that are not included in this report. The purpose of this paper is to provide a picture of the different deployed applications and not a comprehensive list of all the applications.

When one specific application has been deployed in different cities, only one city has been included in this report, to avoid duplication of the same application and to offer a more complete overview about the state of art.

One of the biggest issues at the time of searching these applications has been to differentiate between the real applications already in use from the several applications that are only *marketed* but not in effect. Finding specific and technical information about the applications has been another problem, because almost all the application information is private, or no technical data are available.

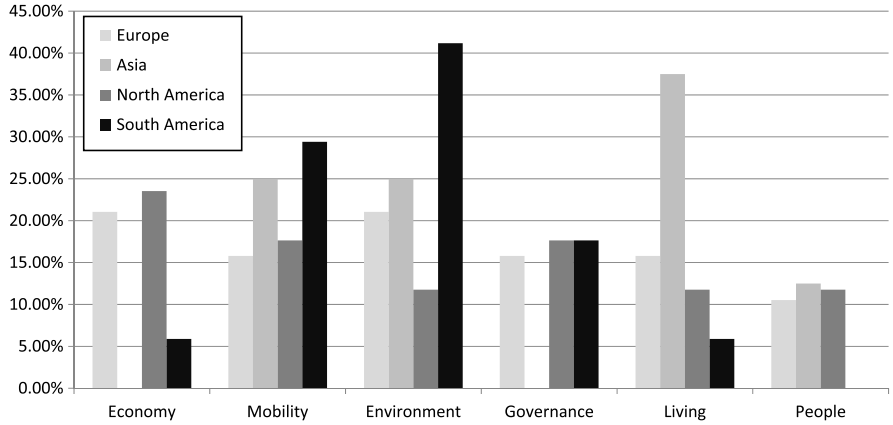

Fig. 2. Percentage of applications from the different classification standards

Europe

Europe is the continent with the largest development in smart cities, with many cities involved in smart development plans, and also supported with financial aid coming from different institutions like the Europe 2020 platform (Manville et al. 2014). Edinburgh and Aarhus are the cities that have been chosen in Europe.

Edinburgh.

- "Town Hall Multichannel" application

  The town hall has a multichannel (web, TV, Internet, and mobile phone channel) platform that enables the citizen to be informed about all issues, events, or useful information related to daily life in the city (City of Edinburgh Council 2014).

  This application offers a more transparent and direct governance, and supports citizens for more active participation and greater interest in public, social, and cultural life. This large and continuous amount of real-time information also allows citizens to have a more comfortable living.
- Web Service Pilot application

  The Web Service Pilot consists on an open web platform for citizens to improve the efficiency of services and user experience by providing their feedback. It is also useful for getting access to basic information, for performing procedures, pay rates and taxes, for surveys, feedback, and electoral votes. In fact, it is a useful application for augmenting the citizen's participation and continuously informing the government about their citizens' opinions and priorities. This application makes it easier for disabled people to deal with bureaucratic duties or voting, therefore adding value to the living standard (North Sea Region Programme 2009).

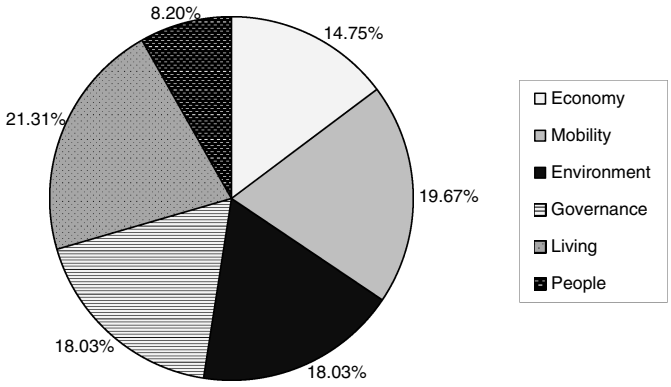

Fig. 3. Percentage of applications from the different classification standards in total

Aarhus.

- Aakhotspot (SmartAarhus) application

  Aarhus has the largest coherent wireless network in Denmark, which is heavily used every day by employees, guests, and its citizens. The network provides new opportunities especially for creating innovative solutions in the city and to utilize and collect a huge variety of data. Providing the wide and free wireless network for all the citizens leads to a useful information system and a participative society. It also is able to connect all the applications and build a real smart city system, avoiding having a system with split applications without any synergy between them (Smart Aarhus 2014).
- Clean and tasty drinking water—The waterworks of Østerby application

  Arhus Water's waterworks deliver clean drinking water from 100 wells. The company controls 10 waterworks, one water tower, and 10 elevated storage tanks. The drinking water is distributed within the city by a 1,500 km-long main water pipe and 46,355 service pipes (State of Green 2014).

  Controlled and supervised from Aarhus Water's headquarters, all 10 waterworks are unmanned. The CRS solution monitors all elements from wells, waterworks, and storage tanks. Recently, the water pipes were included in the CRS solution by monitoring distribution wells in the pipe system. The CRS system and the distribution wells are an effective tool to monitor for potential pollution, pressure, flow, and water loss. The loss of mains water is very low, only around 5–7% and despite the high water quality and secure distribution, a liter of water costs less than 0.50 €.

  The new building is located on a small hill on the western side of the site. Consequently, the water treatment, which cannot be exposed to daylight, is situated in the western side of the building. The offices and other rooms are located in the eastern side of the building, thus facing the light and the panoramic view.

  The building composition and the chosen materials narrate a story of simplicity, cleanness and highly prioritized hygiene. The plant consists of concrete, poured in situ, stainless steel, coated zinc, and unhewn stone. The water treatment at Østerby Waterworks undergoes a simple treatment. The treatment of the groundwater is based on a two-step process: aeration and filtering. The aeration comprises atmospheric air blown up through the water, and thereby oxidizing iron and manganese, and removing sulfide dioxide. After aeration, the water goes

through a gravitation sand filter that removes the oxidized iron and manganese. After treatment, the water is pumped from the waterworks to the storage tanks.

Asia

In Asia, large differences are evident between different countries, and even in the same country there are big differences between regions and cities. Almost all the smart developments are concentrated in the megacities, with some cities in the top of the world smart ranking. The remaining areas outside these cities are far from the smart city concept. Singapore and Beijing are the cities that have been chosen in Asia.

Singapore.

- Live Singapore Project

  The Live Singapore project combines basic data from mobile devices with the weather forecasts to improve the flow and location of taxis. Live Singapore is a project led by the MIT SENSEable City Lab (MIT 2014). Live Singapore uses real-time data recorded by various communications devices, microcontrollers, and sensors to analyze the pulse of the city, telling residents how they can reach their homes fastest, reduce their neighborhood's energy consumption, and find a taxi when a rainstorm hits.

  This application affords many possibilities, like mobility and safety advantages (*living*), use as a statistical tool for energy savings (*economy*), or providing useful real-time information of daily activities (*governance*).
- Water management program

  Singapore has a world-class water management program consisting of rainwater catchment, wastewater recycling, and desalination. As the island lacks many natural resources, Singapore must reduce their dependence on external resources. The application is environmentally friendly with consequences on the economy and on the source management of the city (INSEAD 2013). For example, this system is able to collect rainwater from some 50 m of super trees.

Beijing.

- Chronic disease management process

  In its chronic disease management process, Beijing University People's Hospital helps patients and clinicians clearly understand what clinical activities took place in the past, what actions should be taken at the point of care, and the next steps to take. Reports and proactive alerts for disease management help physicians to better serve the needs of their patients and improve outcomes.

  The economic cost for the update of all Chinese healthcare system is estimated as US$124 billion (IBM Research 2010).
- Digital China support project

  Digital China is a company that provides electronic business platforms, solutions, and services. They span a range of different industries, from banking and telecommunications to the government and public sectors. Leveraging its partnership with over 100 top IT vendors worldwide, Digital China has become the largest integrated IT service provider in China (Digital China 2014).

  It supports governmental efforts to provide services to its citizens. The local government offices are connected together in a unified platform; citizens use a single identification card, which will allow them to access various services, including healthcare services, public transport, and personal identification.

North America

North America and Europe have performed the largest investments in smart city applications. North America has probably the biggest network of smart meters and the largest smart grid deployed in the world. It also has several surveillance systems for reducing crime rates in the most conflictive cities. Finally, open information and a participation portal are also highlighted (Kaufman 2012).

New York and Edmonton are the cities that have been chosen in North America.

New York.

- New York open data system

  New York's Open Data system provides data that is often in a nontextual format and deals with different topics (medical, geographical, weather, biodiversity, related utilities, etc.). These data are usually from the public administration projects that have been financed with public money or created by a public institution, sharing the information using social networks (City of New York 2014).

  This open database provides citizens with detailed information about transportation, health, social services, recreation, and other topics. Living and Governance are the two beneficiated smart topics, offering a picture of all the public service points, plus other interesting information (City of New York 2013).
- Do not eat application

  This application combines the use of data and location information to raise service alerts when possible health risks are detected. The *do not eat* application implemented in New York alerts users with a notification when the user enters a restaurant that does not meet public health standards. The objective of this application is mainly to offer better information about the quality of their meals, for a more healthy lifestyle, and thus better living (NYC Health 2013).

Edmonton.

- Traffic data application

  This application is aimed to improve traffic congestion and road safety in Edmonton, through the analysis of traffic data and with a real-time advising system. It helps to avoid traffic congestion and risky road situations, redirecting the vehicles as a function of the circumstances of the road (City of Edmonton 2014b). This application impacts directly the mobility and safety of vehicle users. As a consequence, a more comfortable and safe ride can be obtained, thus improving the living standards.
- Edmonton ETS Live bus finder

  ETS riders can send an email to ETSLive@edmonton.ca and get real-time departures for Smart Bus routes 7, 57, 111, and 128, and scheduled departure times and maps for all other routes sent directly to your desktop or mobile device in just a few seconds (City of Edmonton 2014a). This application affords citizens the opportunity of more informed and organized mobility. Apart from the mobility advantages, it allows to save time and money compared to inefficient displacements. It also encourages citizens to use public transport, by making it faster and easier to use and so reducing the number of single private vehicle users.

South America

South America is actually making a big effort trying to catch up to Europe and North America in the smart cities competition; their biggest profits are on public sustainable and efficient transport systems, like the Bus Rapid Transit (BRT) systems, which along with metropolitan area pollution and crime are the biggest issues. Big differences are found between different regions and cities, with nearly all the action plans applied in the biggest and more developed cities.

Bogota and Rio de Janeiro are the cities that have been chosen in South America.

Bogota

- Bogota BRT System

  Bogota's bus rapid transit (BRT) system is among the most extensive and used public bus system in the world. The first

phase cost $240 million for 41 km. The second phase of 388 km is projected to cost $3.3 billion, only 10% more than a previously proposed underground project of 30 km would have cost. This will permit to save a lot of money and to offer a nice and fast public transportation system (Metro en Bogota 2014).

The second phase is in progress, with 112 km done for now. This is mainly a mobility application, which has an environmental consequence, reducing the amount of single vehicle users and thus reducing the city's pollution (Villareal 2012).

- Bogota E-Taxi fleet

  The two objectives of this application are environmental and mobility. The project consists of a wholly electric taxi fleet with the collaboration of the Chines BYD company. The fleet is being expanded after a good reception from citizens about the project, adding more cars and new charge points, for a broader network of E-taxis (BYD 2014).

Rio de Janeiro

- Integrated operation center

  Rio's integrated operations center was developed with the support of IBM, which allows real-time monitoring of issues such as weather, safety, and traffic emergencies. The system is especially important for protecting lives in the city's poor mountainside communities, called *favelas*. In these places, there is no sewer system and usually neither public cleaning support; consequently, tens of thousands of people live in areas where there is a high risk of flooding and slides (IBM Portal 2014).

  The project is now finished after the investment of $14 million. The integrated operation center adds value to all the European smart city classification standards: the main objectives of this smart application are focused on mobility issues and trying to avoid natural disasters, but it has a direct effect on the environment and on economic savings. Also, the acquired data can be really useful for governance issues, providing a huge amount of data that can be analyzed and used for new projects and ideas. It is one of the main smart applications, crucial for the correct control, monitoring, and use of the acquired data (IBM 2013; Alt-Simmons et al. 2011).

- Digital map of hot spots

  This digital map enables city staff to tackle issues such as the elimination of accumulated rubbish (which can attract mosquitoes that cause health risks like dengue) and identifying and marking the problematic points as hot spots for a faster reaction of public forces. This system is always being updated, for a more exhaustive control, and to increase the mapped area of the city (Armazén de Datos 2014).

  This application addresses the applications of living, governance, and people. By acquiring the data from citizens and from public services, the government has a more concrete vision of the possible dangerous points, and the capacity to act in a faster and more specific way, focusing directly on the hot spots.

Analysis of the Examples

Almost all the examples are area-specific applications; in fact, it is really hard to find holistic approach applications. However, it can be noted (as shown in Table 1) that some cities (like Lyon, New York, Singapore, or Bogota) are focusing their efforts on trying to develop a more interconnected network of applications. This medium level of integration between the applications can be the path to get closer to a more holistic interpretation of the smart city concept.

Unfortunately, often the applications are designed as isolated tools and not as a part of a network of applications. The different applications are often not interconnected; there is no synergy between the different applications because each one is managed as an individual business. This is one of the biggest problems of current smart city development: the applications usually are focused on business or marketing investments, not on a service for the citizens, managing a more sustainable way of living, a more stable economic growing, a way of working with faster, more comfortable, nor cleaner technologies.

Just thinking of the economic savings that could be realized if all the applications would be connected and would work as a tool on service of all the citizens, of the companies, and the government highlights the importance of interconnection. Time, money, and resource savings are limited by misconceptions of smart cities. The keyword of this holistic approach is communication, the total interconnection between applications, people, and government.

The way to interconnect the applications and services in this holistic approach is by planning for this application network during urban development of the cities, integrating all these applications into the structure of the city. Each one of the projects must be specific for each urban situation, taking advantage of the positive aspects and trying to diminish the negative ones.

As many facilities are given for more potential users, the investments will be amortized faster, and the effects of these holistic approach applications will be faster. The main users of this technology will be the citizens, so this entire network must considered a network of services. This will open new opportunities for more suitable and useful systems for citizens. It makes no sense to build a system of applications that is not interesting for citizens, because it will not be used and as consequence it will be useless.

There are some plans for holistic applications that try to develop smart districts, or smart cities as a unique thing and not as a list of concrete applications. These are many projects that are not implemented already. All othese new plans are in new districts and cities that are grown from nothing, and big investments are necessary to develop them.

Conclusions

Considering the city as a complex and dynamical organism makes it difficult to find the approach and necessary expertise to reach fast and easy solutions. However, this is necessary to accomplish powerful solutions at the different scales of the city: buildings, districts, urban, etc. Skilled expertise is needed for the management, development, and governance in the world's cities. A holistic approach looks at the purpose and not only at the tool. Often, many smart city applications offer good tools, but they do not have a clear larger purpose in the development and sustainable growth of the city.

This paper has provided a multidisciplinary analysis of applications from cities throughout world. An analysis of the awareness of the interconnection between the different topics has also been included. Only a few cities offer weak integration attempts but this is interpreted as the correct way to get closer to the holistic approach.

In summary, many good tools exist but a limited unitary vision of the cities. This scenario is a mirror of the cultural situation that is missing in the technology approach. The city is a complex and dynamic aggregation of relationships and technology; these are strategic tools, but like in all tools, the developer hands are the ones that conceive, use, and define the purpose and the idea of the tools in cities. Smart cities are not only an aggregation or a merger of some applications, they represent a new cultural idea of cities. Technology is a driver, a facilitator for the city development, but if there is not a strategy and a purpose that technology must follow, the risk is

disorder. It is therefore important to understand and define a clear purpose.

The impression exists that there is not a correct approach for smart cities. Thus it is important that the city develops solutions and applications. If nobody informs the users how to use the application, no advantage can be realized by the application. The lack of a city's vision causes smart city applications to fail and to have few users. A holistic approach involves the meaning of the city, the global picture of it.

Democracy, participation, urban design, ICT, and telecommunication are all components of the new strategic vision for cities. The problem of choosing the correct approach involves the culture and idea of the city for tomorrow. Which city do we want for tomorrow? For answering this question, the necessary approach is to shift the focus from technology to the people.

References

Alt-Simmons, R., Gabrieli, J., and Hermann, G. (2011). "Consider an analytic centre of excellence, and other ways to create more value." SAS, Cary, NC.

Armazén de datos. (2014). "Information about the city of Rio de Janeiro." ⟨http://portalgeo.rio.rj.gov.br/amdados800.asp?gtema=15⟩ (Mar. 2015).

Borges, J. L. (1949). "The Aleph." Adelpi, Milan, Italy.

BYD. (2014). "Bogotá launches the largest all-electric taxi fleet in South America." ⟨http://www.byd.com/na/news/news-172.html⟩ (Mar. 2015).

Ceder, A. (2004). "New urban public transportation systems: Initiatives, effectiveness, and challenges." *J. Urban Plann. Dev.*, 10.1061/(ASCE)0733-9488(2004)130:1(56), 56–65.

City of Edinburgh Council. (2014). "Edinburgh Council's social media accounts." ⟨http://www.edinburgh.gov.uk/socialmedia⟩ (Mar. 2015).

City of Edmonton. (2014a). "ETS trip planner." ⟨http://etstripplanner.edmonton.ca/⟩ (Mar. 2015).

City of Edmonton. (2014b). "Transportation data." ⟨http://www.edmonton.ca/transportation/transportation-data.aspx⟩ (Mar. 2015).

City of New York. (2013). "NYC open data." ⟨https://nycopendata.socrata.com/⟩ (Mar. 2015).

City of New York. (2014). "The official website of the city of New York." ⟨http://www1.nyc.gov/connect/social-media.page⟩ (Mar. 2015).

Delucchi, M., and Kurani, K. (2014). "How to have sustainable transportation without making people drive less or give up suburban living." *J. Urban Plann. Dev.*, 10.1061/(ASCE)UP.1943-5444.0000172, 04014008.

Digital China. (2014). "Leading Sm@rt city in China." ⟨http://www.digitalchina.com.hk/html/index.php⟩ (Mar. 2015).

Doherty, M., Nakanishi, H., Bai, X., and Meyers, J. (2010). "Relationships between form, morphology, density and energy in urban environments." *Global Energy Assessment Background Paper*, International Institute for Applied Systems Analysis, Laxenburg, Austria.

EC (European Commission). (2011). "Regional policy contributing to smart growth in Europe 2020." Brussels, Belgium.

Giffinger, R., Fertner, C., Kramar, H., Pichelr-Milanovic, N., and Meijers, E. (2007). "European smart cities." ⟨http://www.smart-cities.eu/index2.html⟩ (Mar. 2015).

IBM. (2013). "IBM intelligent operations centre for smarter cities." IBM, Somers, NY.

IBM Portal. (2014). "City of Rio de Janeiro and IBM collaborate to advance emergency response system; access to real-time information empowers citizens." ⟨http://www-03.ibm.com/press/us/en/pressrelease/35945.wss⟩ (Mar. 2015).

IBM Research. (2010). "Peking University people's hospital partners with IBM to build China's first evidence-based patient centric care system." ⟨http://www-03.ibm.com/press/us/en/pressrelease/32126.wss⟩ (Mar. 2015).

INSEAD. (2013). "Tackling Singapore's water shortage." ⟨http://centres.insead.edu/innovation-policy/events/documents/Singapore-WaterShortage.pdf⟩ (Mar. 2015).

Johnson, B., and White, S. (2010). "Promoting sustainability through transportation infrastructure? Innovation and inertia in the Kansas City metropolitan area." *J. Urban Plann. Dev.*, 10.1061/(ASCE)UP.1943-5444.0000027, 303–313.

Kaufman, S. M. (2012). "How social media moves New York." NYU Rudin Center for Transportation, Region II Univ. Transportation Research Center, City College, New York.

Li, Y., and Liu, A. (2013). "Analysis of the challenges and solutions of building a smart city." *Proc., 2013 Int. Conf. on Construction and Real Estate Management (ICCREM)*, ASCE, Reston, VA, 1511–1515.

Manville, C., et al. (2014). "Mapping smart cities in the EU." ⟨http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/507480/IPOL-ITRE_ET(2014)507480_EN.pdf⟩ (Mar. 2015).

McFedries, P. (2014). "The city as system." *IEEE Spect.*, 51(4), 36.

Metro en Bogota. (2014). "Metro in Bogota." ⟨http://www.metroenbogota.com/⟩ (Mar. 2015).

Midgley, P. (2009). "The role of smart bike-sharing systems in urban mobility." *Journeys*, Land Transport Authority (LTA) Academy, Singapore, 23–31.

MIT (Massachusetts Institute of Technology). (2014). "LIVE Singapore!" Cambridge, MA, ⟨http://senseable.mit.edu/livesingapore/⟩ (Aug. 2014).

Nadeem, T. (2011). "Smart mobility: Next generation transportation system." Workshop on Developing Dependable and Secure Automotive Cyber-Physical Systems from Components, Troy, MI.

Naphade, M., Banavar, G., Harrison, C., Paraszczak, J., and Morris, R. (2011). "Smarter cities and their innovation challenges." *Computer*, 44(6), 32–39.

Norman, J., MacLean, H., and Kennedy, C. (2006). "Comparing high and low residential density: Life-cycle analysis of energy use and greenhouse gas emissions." *J. Urban Plann. Dev.*, 10.1061/(ASCE)0733-9488(2006)132:1(10), 10–21.

North Sea Region Programme. (2009). "Smart cities—Edinburgh." ⟨http://www.smartcities.info/edinburgh⟩ (Aug. 2014).

NYC Health. (2013). "Restaurant inspection results." ⟨http://www.nyc.gov.shtml⟩ (Mar. 2015).

Roche, S., Nabian, N., Kloeckl, K., and Ratti, C. (2012). "Are 'smart cities' smart enough?" *2013 Global Geospatial Conf.*, Global Spatial Data Infrastructure Association (GSDI), Quebec City, Canada.

Russo, F., and Comi, A. (2011). "Measures for sustainable freight transportation at urban scale: Expected goals and tested results in Europe." *J. Urban Plann. Dev.*, 10.1061/(ASCE)UP.1943-5444.0000052, 142–152.

Smart Aarhus. (2014). "WIFI." ⟨http://www.smartaarhus.eu/wifi/⟩ (Mar. 2015).

Staley, S., and Claeys, E. (2005). "Is the future of development regulation based in the past? Toward a market-oriented, innovation friendly framework." *J. Urban Plann. Dev.*, 10.1061/(ASCE)0733-9488(2005)131:4(202), 202–213.

State of Green. (2014). "Clean and tasty drinking—The waterworks of Osterby." ⟨http://stateofgreen.com/en/profiles/city-of-aarhus⟩ (Mar. 2015).

Taylor, P. J., and Johonston, R. J. (1995). "Geographic information systems and geography." Chapter 3, *Libro: Ground Trugh: The social implications of geographic information systems*, J. Pickels, ed., Guilford Press, New York, 67.

Villareal, R. (2012). "Bogota bus rapid transit." Transportation Research at McGill (TRAM), Montreal, Canada.

Yuan, Y., and Li, Y. (2014). "Research on the construction of innovation-driven smart cities." *Proc., 2014 Int. Conf. on Construction and Real Estate Management (ICCREM)*, ASCE, Reston, VA, 1719–1726.