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Geomatics and Smart City: A transversal contribution to the Smart City development

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Abstract. Information and Communication Technologies (ICTs) revolutionize the ways different urban actors communicate and interact. Geographic information technologies are of key importance too for the deployment and implementation of ICTs in the Smart City, because of the central role they may play as decision-making support tools. Indeed, they give quick access to different layers of information that may be combined and integrated to facilitate analysis of a situation and make the best decisions. However, such a central role is rarely acknowledged. In this paper, we propose to define the extent of the concept of Smart Cities and some of the distinctive features that it should display to support its sustainability. We will then propose an overview of the current and forthcoming developments in the geospatial domain to illustrate the opportunities that may arise for Smart City initiatives. The paper will also discuss the issues and challenges that need to be addressed when considering these emerging geomatics-driven solutions in the context of Smart City.

Keywords: Smart City model, geospatial information, geospatial intelligence

1. Introduction

Cities and communities around the world are facing significant challenges due to the ever growing urban population. Information and Communication Technologies (ICTs) are key to make this growth sustainable. They can help connect people and businesses and enable innovations and new solutions that will improve the efficiency of physical infrastructure, including roads, water supply, wastewater and emergency services. The Smart City movement has emerged from this vision of sustainable cities making better use of ICTs to improve the services that support urban operations and services (ex. transport, power supply, entertainment). While most cities see the real value in adopting Smart City objectives, there is still a lack of consensus and clarity about the Smart City underlying model and core technologies to develop it. Cities are complex systems composed of numerous interacting components that evolve over multiple spatiotemporal scales.

Therefore, geographic information technologies are preponderant to provide a response to these issues at all scales. While location data is now commonly regarded as the fourth driver in the decision making process [9], geomatics is not often clearly identified as a key ingredient of Smart City development.

In this paper, we propose to define the extent of the concept of Smart Cities and to introduce a new model, inspired by the work and models of other important stakeholders and promoters of Smart Cities. We will then underline geomatics pervasiveness in the proposed Smart City model components through

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dedicated use cases. With the progresses and innovation of geospatial technologies, geomatics is emerging as a key driver to create new, smart applications. An overview of recent and forthcoming developments in the geospatial domain will be provided to illustrate the opportunities that may arise for Smart City initiatives.

2. Smart cities and smart communities

2.1. Smart City concept

Since 2008, half of the population of the Earth lives in an urban context. This is an irreversible tendency that changes completely the dynamics inside the city and the way we should organize the urban governance in order to keep prosperity, attractiveness, human well-being and sustainable development. The quick growth of urbanization allows much power to the city level of governance because it is linked with the quality of live and services offered to citizens on an everyday basis. Cities have become an important actor for innovation and development, and economic growth. As pointed out by the Canadian Chamber of Commerce [13], the attractiveness of a city is important in order to drive highly educated workers and immigrants. *"They are centres of business, generators and suppliers of financial capital, important trade hubs for both goods and services, and the focal points of global commerce. They house substantial infrastructure assets and major institutions that power regional prosperity and the nation's quality of life."* [13] If the city is not well organized and equipped to face the stress of rapidly growing urbanization, chaos quickly takes place. The quality of life, the security, the effectiveness of citizens' services, the economic development and attractiveness, and the quality of the environment may decrease quickly affecting the life and prosperity of the community.

The Smart City concept seems to be a key solution to challenges brought by a fast growing urbanization such as urban sprawl, environmental challenges and sustainability, transportation, high costs of management, civic participation, energy constraints, enhancement of cultural heritage, citizens' quality of life, etc.

Although there are many definitions of the Smart City concept, we focus on four of them that present an interesting convergence.

According to IBM: *"A city is an interconnected system of systems. A dynamic work in progress, with progress as its watchword. A tripod [Infrastructure, operations, people] that relies on strong support for and among each of its pillars, to become a smarter city for all."*[1]

MIT focuses on the fact that *"[. . .] cities are systems of systems, and that there are emerging opportunities to introduce digital nervous systems, intelligent responsiveness, and optimization at every level of system integration – from that of individual devices and appliances to that of buildings, and ultimately to that of complete cities and urban regions."*[2]

For the Forrester Research Institute, *"The use of smart computing technologies to make the critical infrastructure components and services of a city more intelligent, interconnected, and efficient."*[3]

[1] IBM, *Smarter Cities – Overview*, http://www.ibm.com/smarterplanet/us/en/smarter_cities/overview.

[2] MIT City Science, *Smart Cities: Vision,* http://smartcities.media.mit.edu/frameset.html.

[3] Forrester Research, in *Smart Grid News*, «Smart Cities: Next Stop For Utility CIOs and CTOs», August 31 2010, http://www.smartgridnews.com/artman/publish/Technologies_IT_and_Back_Office/Smart-Cities-Next-Stop-for-Utility-CIOs-and-CTOs-2959.html#.UR0GV-i6Lck.

The European Union proposes a definition that puts emphasis on sustainable development and quality of life. "*Smart Cities combine diverse technologies to reduce their environmental impact and offer citizens better lives. This is not, however, simply a technical challenge. Organisational change in governments – and indeed society at large – is just as essential. Making a city smart is therefore a very multidisciplinary challenge, bringing together city officials, innovative suppliers, national and EU policymakers, academics and civil society*."[4]

The IBM and the MIT definitions present Smart Cities or Smart Communities as a system of systems interconnected by ICTs. The growth of interconnectivity allows a new efficiency if the administration of a city uses the technology to link and integrate the different systems and to break the "silos". Technology deployment alone is not sufficient to make a smarter city. Such an approach is simplistic and cannot generate the expected changes in the context of a Smart City project. Unfortunately we cannot get there, when there is no comprehensive and integrated approach. There has to be a global reflection on the transformations required by a Smart City project. The many systems of the city (transportation system, resources management systems, waste products management, etc.) have to be linked together and the interactions between them have to be well planned and integrated. Of course ICTs are essential to move a large load of information very quickly but all these data must be used properly to add efficiency.

In a Smart City we assist the deployment and integration of ICTs *"including wireless and broadband connections, advanced analytics software and intelligent sensors to achieve significant improvements in efficiency and in the quality of life, and to help change behaviour among residents, businesses and government so cities can grow in a more sustainable way."* [13] Being or becoming a Smart City is a question of prosperity, sustainability and well-being for the governance structures, economic partners, and citizens inside the community.

According to the development priorities of different countries and their progress in the implementation of projects of smarter cities, there are variations in the models and in the priority development thematic of Smart Cities. In the definition proposed by the European Commission, the sustainable development of the city is considered as an important and collective goal. In this context and related to this definition, it is not surprising that in a majority of European writings or information on Smart Cities and communities, the environmental concerns and the global issue of sustainable development occupy an important place. This tendency is more specific to Europe, and the issue of sustainable development is less present in the writings of other countries on Smart Cities' definitions or goals. One of the reasons that may explain this difference may be the importance of the "Green city" label in European cities, prior to the concept of Smart Cities in Europe. This observation is a tendency pointed out by an overview of the projects selected by two contests, the Top 21 of the Intelligent Community Forum (ICF) Challenge[5] and the IBM Smarter Cities Challenge[6] recently presented by the Institute for Information Technologies and Societies (IITS) of Université Laval.[7] However, as the object of this article is to highlight the contribution of geomatics to the development of the Smart City, we will only focus on this aspect, in the present paper and go no further with the comparison of the guidance of the various countries in the development of Smart Cities.

[4]http://www.eu-smartcities.eu/.

[5]https://www.intelligentcommunity.org/index.php?submenu=Awards&src=gendocs&ref=Smart21&category=Events&link=Smart21.

[6]http://smartercitieschallenge.org/index.html.

[7]https://www.itis.ulaval.ca/cms/site/itis/page81388.html.

2.2. *Smart City model*

Inspired by the work of Rudolf Giffinger (2007), researcher at the Vienna University of Technology, Doran et al. [6] has developed a *Smart City Model* describing the three main components that the Smart City system aims to integrate (cf. Fig. 1):

1. The Economic component that includes public administration, economic actors, universities and colleges. It covers governance models, urban regeneration, open data, big data, bandwidth, mobility, cloud computing, security, business intelligence, etc.
2. The Environmental component that includes resources and managerial infrastructures. It covers water, air, energy and waste management, public and alternative transportation, geographical information, green buildings, green spaces, smart growth, climate change measurement, etc.
3. The Social component that includes citizens. It covers community life, urban mediation, participatory democracy, social innovation, human-scale cities, civic participation, proximity services, etc.

The three components of the proposed Smart City Model are in balance with the sustainable development model. This balance is needed in order to create an innovative, prosperous, civic and sustainable Smart City.

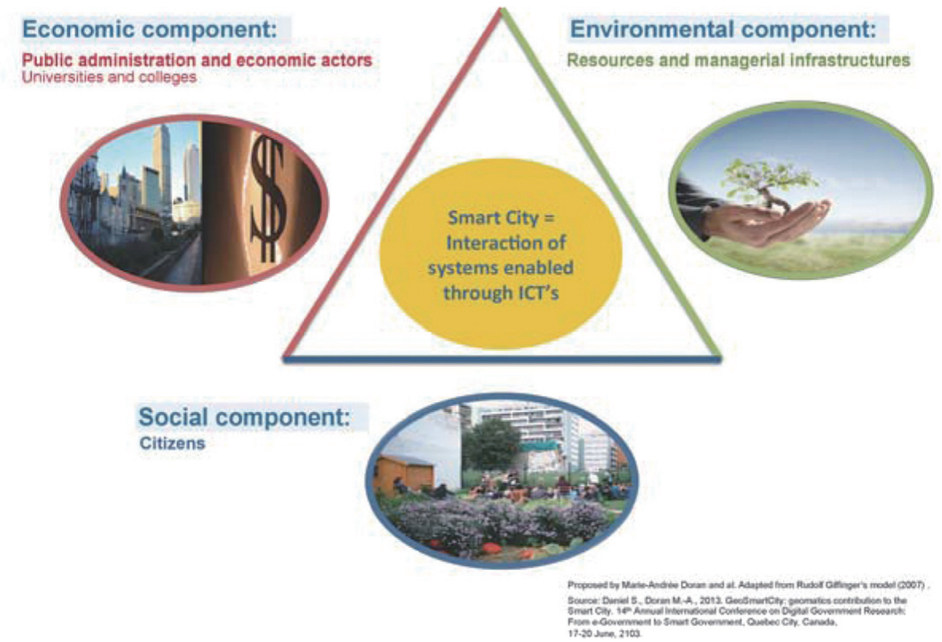

Fig. 1. The Smart City Model. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/IP-140330)

2.3. *Some distinctive features of a Smart City*

A Smart City is a solution that allows the city to avoid a chaotic development and thus sustains its attractiveness, and supports its positive development, to assure an efficient management of resources, to show case the citizens' consultation in order to stimulate innovation and collaborative creativity, to sustain an enjoyable quality of life to its citizens, to promote a sustainable development, etc.

2.3.1. Services to citizens

The growing urbanization challenges the governance structures of the city and the new tools offered by the use of ICTs may add flexibility to respond to citizens' needs of services. A Smart City aims to deliver better services to citizens, to give them real-time information that may help them to make the good choices and contributes to solve everyday problems in a city.

Transportation, security, available parking places, water or energy consumption, information about traffic jams, and alternative routes, snow removal, goods, services, events. These are a few examples why ICTs are needed to give quick information to citizens and to deliver services more efficiently. On time and well provided information can simplify everyday life in a city and help people make decisions.

2.3.2. Citizen participation

Because people live more and more in cities, they are concerned by all the changes that may take place around them. They want to participate in the debates, to be considered and listened to by the decision makers. They want to be actors of change as much as decision makers and businessmen are. ICTs enable access to information and may enable the citizens to play a new and more active role.

2.3.3. Open government, transparency and confidence

Because of the need to pay attention to the way citizens want to interact with the city administration, open government and transparency are requested to maintain or to increase the confidence of citizens.

Open Data and access to information are essential in the process of increasing positive interactions between citizens and the city administration. ICTs should aim to enhance the communications and interactions between citizens and public administration.

2.3.4. Concerted, efficient and sustainable management

Quality of life and sustainable management and development are important values and goals for a Smart City. The rapid growth of cities strengthens the importance of a good management of resources (water, air, energy, wastes) in order to maintain the quality of life, health, and the quality of environment in the city. The development of a Smart City is not possible without a strong environmental component.

3. The transversal role of geomatics in the Smart City Model

3.1. Pervasiveness of geospatial information

As mentioned above, a Smart City is often defined as a city in which ICTs are merged with traditional infrastructure using new digital technologies. The integration of ICTs and services into existing city infrastructures provides a network of connections among people, goods, utility control systems, materials. Requests for information, services as well as their supply can be driven through this network. While deeply present in the three components of the proposed Smart City model (cf. Section 2.2), geomatics is not often clearly identified as a key ingredient of Smart City development. However, the use of geomatics is one requisite for establishing a Smart City given the pervasiveness of geospatial information in the management tools and services provided to the citizens and decision makers.

While the definitions of the Smart City concept may vary, the envisioned approaches [1,4,5] often rely on technologies that deliver information and control equipment through various services infrastructures. To efficiently deliver services based on the genuine needs of consumers and citizens, control systems

Table 1
Spatially embedded questions arising in projects to make the city smarter

Index	Spatially embedded questions	Information required
1	Where is this?	Location
2	What is happening where?	Event at a location
3	Is this available here?	Presence of a thematic content at a location
4	What is the amount of this here?	Statistics per location
5	What is the amount of this per time unit?	Data flow per location
6	What is the best route?	Routing
7	What is here?	Spatial content of an area
8	What was here?	Historical spatial content of an area
9	What will be the impact of doing this here/of this event occurring here?	Simulation of the interaction of an event with the spatial content of an area
10	Can I do that here?	Correlation between an action and the spatial content of an area

NOTE: “this” refers to: services, resources, goods, infrastructures, etc.

need to know where the supply should be guided at a particular time. Location is therefore core information. Furthermore, to meet demands right on time, these infrastructure units need to be agile, and have the flexibility to adapt to changes and emergencies. As such, they require being aware of their environment and of what is happening in their vicinity. Situational information including geographical characteristics (ex. topography, arid areas . . .) and spatial understanding capabilities participate significantly in the design and operation of Smart City service and management infrastructures.

Efficient transportation systems are one of the defining features of Smart Cities. Mobile platforms and sensors with embedded GPS (Global Positioning System) are central to the emergence of smart mobility. Transportation modes (ex. car, bus, subway) can be inferred from the GPS data, from which service providers can design smart route and recommendations. The displacement velocity, the flow or rate of people, goods, resource through specific infrastructure can also be monitored. Smart routing services also require integrating the spatial context of the itinerary. Spatial context refers to context awareness generally understood as the ability of an application or a device to adapt itself to its environment [10]. As an example, the best route a police car should follow to reach a crime scene will rely on its current location, provided by its GPS, and the destination address. However, taking into account road works in its immediate surrounding will yield to a more relevant and efficient route.

The previous paragraphs demonstrate that location information, situational information, mobility velocity information and context information are required on a continuous basis when managing urban infrastructures. To further illustrate how geospatial information is pervasive in the issues city managers and service providers need to tackle, Table 1 provides a synthesis of the spatially embedded questions that frequently arise when coordinating the various systems operating or controlling urban infrastructures.

These questions are purposely generic to underline their preponderance in the three components of the proposed Smart City model. Thus, the location “here” expressed in the various questions encompasses diverse scales, namely: micro, meso, macro. They are not specific to the city and could apply to a broad range of entities like, for instance, the citizen or utility. If so, the micro scale would refer to a building, individual or power line, the meso scale to a district, citizens or network of electricity lines, the macro scale to the city, a community or power grid. The following section illustrates how questions in Table 1 translate into practice.

3.2. Recent worldwide Smart City initiatives using geomatics

Amphibious Architecture[8] is a collaborative project in New York City. It involves a network of floating tubes in the river, which places sensors below the water and lights above the surface. These sensors monitor water quality, presence of fish and human interest in the river ecosystem, providing information which the lights react to in real time. Geospatial information involved in this project relates to the presence of fish (i.e. Table 1 – question 3) and water quality (i.e. Table 1 – question 4: amount of water contaminants).

Fig. 2. The city of New York uses sensors in order to monitor the quality of water and the presence of fish in the river (Photo credits: cdn.guggenheim.org/BMW/images/2011/cycle1_nyc_events/2011-08-19_2pm_spurse.jpg).

OPTIMOD LYON[9] is a project lead by the Greater Lyon Urban Authority ("Grand Lyon"). It experiments with innovative solutions to improve urban mobility for travelers and freight professionals. The project relies on an information platform integrating mobility information in data warehouses. Among the services that will be provided, there are: hourly traffic forecast (i.e. Table 1 - question 5) and a journey planning mobile application, based on real-time data (i.e. Table 1 – question 6).

Similarly, Nice (France) deployed in 2012 its smart parking management. Using a network of sensors embedded in the public roads, car drivers can know the available parking spaces in the city and the best route to reach them. The information is provided in real time through a mobile app relying on the phone GPS (i.e. Table 1 – question 1).

In Quebec City, snow clearance equipment has been provided with GPS. A geospatial solution gathers technical information about the work that is carried out and maps in real time the optimal route for completing the snow clearance of roads and pavement (i.e. Table 1 – question 6). In addition, the solution measures the amount of salt spread on the road (Table 1 – question 4).

After the terrorist attacks that occurred in 2004, the city of Madrid has developed a coordinated emergency solution based on a centralized model for command and control. Such a system provides comprehensive, real time view of event across the city, allowing a better coordination of emergency crews (average responding time decreased from 24 minutes to 8 minutes). The solution has been designed based on the fact that emergency managers not only need to coordinate activities, but also require a thorough understanding of everything happening in the city (i.e. Table 1 – question 2) so as to properly allocate limited resources to provide the best response to each incident.

[8] http://www.thelivingnewyork.com/amphibiousarchitecture.htm.
[9] http://www.optimodlyon.com/.

Fig. 3. In the cities of Lyon and Nice, traffic and parking lots are managed thanks to mobile apps. They offer alternative propositions on a real-time basis (Photo credits: www.arrivalguides.com/Destinations/LYON/Images/thecity_large.jpg; farm8.staticflickr.com/7269/7536910258_cb8367ea22_z.jpg). (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/IP-140330)

The previous examples clearly illustrate how geomatics, through its technologies, provides solutions to capture, process, manage and disseminate spatial data over various scale and time spans. It also proposes models and approaches to explicitly exploit data spatial dimension when conducting analysis towards decision making. The next section proposes an overview of modern geomatics technologies and approaches and underlines how geomatics will strengthen its position as a key driver of Smart City initiatives.

3.3. Overview of geomatics technologies opportunities in support of Smart Cities

Geomatics applications are numerous and range over a broad variety of domains such as forestry, health, urban management, civil security, tourism ... Geographic information systems (GISs) are commonly used by private and governmental organizations to display geospatial and location-based data (ex. population census data) and conduct spatial analysis over diverse thematic layers. They often rely on airborne and satellite remote sensing data to obtain an up-to-date view of the physical world. Over the years, these technologies have helped monitor, gain knowledge and manage lands and resources and mitigate related risks. Geomatics technologies are growing rapidly. Recent developments in GISs, Global Navigation Satellite Systems (GNSSs), remote sensing, web-services and location-based services and technologies have led to modern geomatics tools that can support innovative solutions for management, governance and citizen participation practices compliant with Smart City objectives.

The past few years have seen a remarkable development in mobile laser scanning (MLS) to accommodate the need for large area and high-resolution 3D data acquisition [14]. Similar mobile solutions relying

Fig. 4. In Quebec City, a geo-system allows the follow up of the snow clearance on a real time basis for better car traffic and better pavement management (Photo credits: Ville de Québec, "Vers une ville intelligente", https://www.itis.ulaval.ca/cms/site/itis/page88729.html). (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/IP-140330)

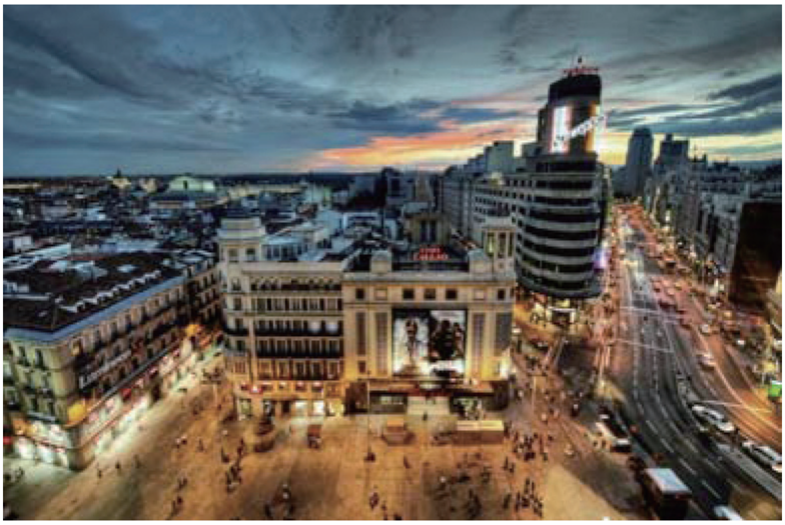

Fig. 5. In Madrid, an integrated security system allows authorities to respond quickly to emergency situations (Photo credits: http://www.flickr.com/photos/cuellar/4670777817/). (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/IP-140330)

on video cameras (ex. GeoAutomation technology[10]) are also available providing sets of point clouds descriptive of the imaged environment. These technologies provide fast, efficient, and cost-effective data collection. They allow very accurate and highly detailed geospatial data to be recorded at scales ranging from region to person. The value of such data sets has already been acknowledged by various Departments of Transportation in the USA and Canada [16]. Preliminary studies demonstrate that more efficient asset inventories and management can be achieved using such technology, limiting time consuming and risky tasks on the field. In addition, ground truth can be brought to the office using the mobile laser point clouds avoiding returning on site for controls and missing measurements.

MLS and mobile video mapping can be conducted using a large diversity of platforms such as cars, trucks, boats, all-terrain vehicles (ATV), bikes etc... They allow acquiring data in areas that were not accessible previously, under different perspectives (bird view versus street view), extending the capabilities to digitize the world, not only outdoor but also indoor (ex. ZEB1 indoor mapper[11]). Among the emerging platforms, it is already anticipated that Unmanned Airborne Vehicles (UAV) / Unmanned Airborne Systems (UAS) will have a strong impact on smaller scale projects in near future. Such platforms will be equipped with sets of cameras providing an image-based point cloud of the ground surface. More frequent data collections will be possible, for a lesser cost, allowing new capabilities in terms of change detection and risk assessment or terrain situation assessment after natural disasters.

MLS and mobile video mapping solutions serve one of the probably fastest growing market segments, which is 3D city modeling [14]. Advanced real-time visualization for location-based systems such as vehicle or mobile phone navigation requires large scale 3D reconstructions of street scenes. Furthermore, the significant added value of these technologies comes in transforming the collected 3D georeferenced point clouds into intelligent 3D models of our urban infrastructure and environment. Not only is this type of semantic description significantly more compact than the raw data, but it supports high-level tasks such as analysis of space usage or planning for renovations. These city models become new mediation tools for communication between city managers and service providers as well as between city or government representatives and the public. As an example, Quebec City leveraged 3D technology to develop a complete and accurate view of its urban ecosystem. The GIS-based 3D model of the city has been used to model risk, assess the impact of new building shadow on public swimming pools or maintain visual harmony between new constructions and heritage properties (cf. Fig. 6), to name a few applications. It has been used so far on desktop platforms.

The constant improvement of broadband internet access facilitates the emergence of online 3D GIS. As an example, Territoire3D®[12] is an online service launched in 2009 proposing 3D models of cities and villages all over France. The solution has been opened first to the public and to public communities for visualization and promotion of territorial assets. Since then, the service has become available to private actors. While the online version does not offer the usual GIS spatial analysis tools, Territoire3D® includes an offline version allowing running simulations. This technology has already demonstrated a significant impact on citizen participation as an enabler of immersive applications. Given the progresses of 3D GIS, it is anticipated that the next generations will rely on augmented reality and run on mobile platform. Mobile Augmented Reality (MAR) is defined as the extension of a user's perception with virtual information [2]. As illustrated in Fig. 7, it can make visible underground infrastructures, facilitating

[10]http://www.geoautomation.be/.
[11]http://www.3dlasermapping.com/.
[12]http://www.territoire3d.com/.

Fig. 6. A history of 3D buildings can be referenced to demonstrate powerful before and after scenarios (image from [8]). (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/IP-140330)

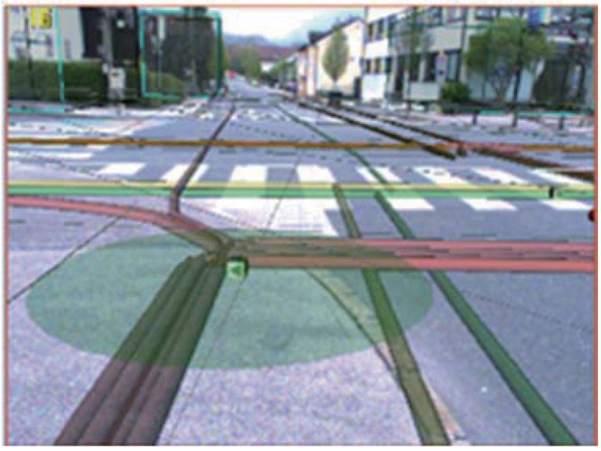

Fig. 7. Project VIDENTE: 3D GIS and augmented reality visualization of underground infrastructures (Photo credits: http://studierstube.icg.tugraz.at/outdoor/). (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/IP-140330)

digging operations and reducing related risks [12]. As such, mobile 3D GIS with augmented reality visualization will constitute a powerful and immersive tool for civil engineers, architects, or decision makers to gain a better understanding and knowledge of their surrounding environment on site and thus make more informed decisions.

A key component of Smart City development is ubiquitous ICT and geolocation infrastructures providing a real time information flow of the position and displacement of everything and everybody. The evolving concept of spatially enabled society stems from this context. The underlined principle is that "*location, place and other spatial information are available to governments, citizens and businesses as a means of organising their activities and information*" [15]. The open access to GPS data has been a strong catalyst of location-based services and applications and an innovation vector in terms of management and control of goods, resources and infrastructures. The new GNSS constellations (ex. GLONASS) and forthcoming ones (ex. Galileo) are expected to strengthen the capabilities to understand city dynamics and meet citizen expectations. They should result in better coverage and less sensitivity to signal obstacles, providing better position precision with cheaper and smaller devices. As such, an increased pervasiveness of spatially embedded data acquisition sensors in people hands, immediate surrounding and urban environment should be expected. The increased accuracy of position sensors in mobile devices, such as smartphones and tactile tablets, will also significantly improve the possibilities to achieve outdoor immersive augmented reality. Current emerging WiFi-based indoor positioning solutions are also opening a new range of mapping services. Google and Nokia (i.e. Destination Maps application) already propose navigation tools in some venues (ex. airports, malls, and retail stores) to find your favorite shop or your boarding gate. Thus the next generation of mobile 3D GIS relying on augmented reality interface is expected to run seamlessly from outdoor to indoor environments, which could be of significant value to emergency crews for instance.

The widespread diffusion of wireless technologies in addition to mobile phone networks has fostered an overwhelming volume of data often referred to as big data. It encompasses interactions over mobile devices being used by people, real time records of sensors connected to infrastructure such as road, water, power networks, posts to social media sites etc... If big data concerns any type of data, a significant ratio of sources streaming information to databases and warehouses is georeferenced. The spatial dimension accentuates the big data challenges that are generally pointed out by the industry [7] namely volume, variety and velocity. Thus the heterogeneity of spatial data types (ex. points, images, polygons, ...), reference systems (ex. Universal Transverse Mercator, World Geodetic System), level of details, reliability (ex. data collection stemming from crowdsourcing or land surveyors) requires adapted data integration approaches to handle inconsistencies. Furthermore, big data analytics tools developed in the IT domain are generally not able to deliver the value associated with spatial analyses. Indeed, such analyses generally required dedicated storage, manipulation and visualization functions that can geographically organise, structure, correlate or mine the data in order to unlock new value that can result in better decision-making and control. Historically, business intelligence (BI) and GIS technologies have followed separate paths. However, Geospatial intelligence (i.e. GeoBI) is currently offering innovative solutions combining the two technologies and providing a more complete picture of the business or operations at hand. GeoBI value lies in its ability to make sense out of the spatial or location information attached to the data, to segment data based on spatial patterns and find patterns of spatial clustering. This adds powerful insights into information patterns that cannot be obtained in any other fashion [3].

The big data topic has been receiving a lot of attention lately, not only for the technological perspectives and innovation it may hold but also for its related economic stakes. Europe's position on big data has been reinforced since it is perceived as a medium for economic growth. Thus, a two-year project (2012–2014), entitled *Big data Public Forum* (http://big-project.eu/), has been funded by the European commission through their Seventh Framework Program. The priority of the project is building an industrial community around big data in Europe. It should contribute to the definition of a strategy that should yield to the successful implementation of the big data economy. Significant budgets have been allocated to research and innovation in areas related to big data and big data analytics (ex. digital content analytics, language technology), not only by the European commission but by European countries as well.[13] Big data is also central in Horizon 2020, the next research, development and innovation program of EU in 2014–2020.

4. Discussion

4.1. The need for spatial intelligence

The distinctive features of Smart Cities (ex. services to citizen, transparency ...) rely on new tools offered by the use of ICTs and geomatics. The previous sections illustrated contexts where geomatics can provide valuable information to take more informed decision and solutions to mediate information or services to citizen. The provided examples underlined the fact that geospatial technologies are already involved in several initiatives. Thus, the argument here is not towards the inclusion of geomatics in Smart Cities since, it is already a work in progress. However, the pervasiness of geospatial information among urban management tools and services raise awareness on the need for a Smart City to be spatially enabled. As mentioned by Roche [19], spatial enablement is not only a matter of GPS data. The concept goes beyond the exploitation of geolocation. It relates to the open data movement where location and spatial information are consider as common goods, and as such, should be available and

[13]http://investissement-avenir.gouvernement.fr/content/programme-d%E2%80%99investissements-d%E2%80%99avenir-115-millions-d%E2%80%99euros-dans-7-projets-de-big-data.

accessible. It addresses the issue of spatial literacy, namely the ability to use the properties of space to communicate reason and solve problems. Not only should geospatial infrastructures and technologies be available to integrate spatial information in city management and services, but service providers, infrastructure operators and decision makers should understand how to organize this spatial information and take fully advantage of it. They should know where, when and how to think spatially. They should understand spatial representations, handle easily 3D models and conduct reasoning based on such visualizations. They should be able to have a critical eye towards the reliability, relevance and validity of spatial information. Citizen participation and empowerment being a key ingredient of Smart Cities, the spatial domain should also be added to citizenship education.

4.2. Technological challenges and issues

The involvement of geomatics in many aspects of the Smart City model has been clearly illustrated in the previous sections. The concepts of spatial enablement and geospatial intelligence underline the role modern geomatics tools are going to play at the various control and management levels of the city dynamics. While geomatics-driven solutions should foster new opportunities to meet Smart City objectives, they could also imply new issues and challenges which should be addressed. The following paragraphs present some of them.

The proliferation of sensors and devices to digitize the physical world highlights the overlap between how urban and geomatics engineers and game builders for instance, collect, visualize, and store representations of the world. Such overlap could be of great benefit if a concerted effort to build re-usable world models were invested (ex. new insights into urban development). As a result, building a 3D model of a modern city would result in a model of use to gamers wishing to build a new game, to urban planners and engineers carrying out planning, and to geographers interested in demographics and sense of place. Ideally, a single model would serve all of these purposes. Significant research on both construction and shared context methods is necessary for this to be realized.

Technology is evolving faster than related regulations. Thus, while UAV has already been acknowledged as a cost effective and robust solution for mapping and digitizing the physical world, most countries still do not have explicit and official regulations to describe UAV legal context of operation. Similarly, there is still a legal void regarding the ever growing number of sensors in the environment and their pervasiveness in people's private life. UAVs equipped with digital cameras have already been targeted as such sensors, especially as their miniaturization is anticipated.

The widespread diffusion of GPS in mobile devices, open data and open maps, like OpenStreetMap, offer unprecedented opportunities to create maps, and to find new ways to represent spatially embedded information. This trend yields new opportunities, for instance, to rapidly update maps after natural disasters and guide the rescue teams such as in Haiti after the 2010 earthquake. However, open access to data raises issues of usage and liability when accident occurs [11].

4.3. Smart City governance: New challenges

Integration and use of ICTs and geomatics tools are indispensable to the development and implementation of a Smart City. However, a Smart City is much more than an extended use of ICTs and geospatial technologies; it is a kind of revolution because it changes so many paradigms particularly in the development model of the city and in its way of governance. The Smart City concept goes much further than interconnections and interactions enabled and facilitated by the use of ICTs and geomatics. There has to be a vision shared by all the actors of the Smart City, by the public administration, economic actors and universities and colleges (Economy component), by the resource and managerial infrastructures (Environmental component), and by citizens (Social component). These new ways of sharing power inside the city will certainly transform our cities' administrations and their governance models. It is not clear yet how the implementation of the Smart City concept will change the structures of governance of our urban administrations and to what extent it will drive the collectivity. How will these new governance patterns rely on ICTs and geospatial technologies? To what extent will they be integrated? Changes are occurring quickly, and our governance structures will have to adapt rapidly. Some important challenges will have to be met, but also a unique chance to maintain sustainable cities.

Around the world, we are witnessing as well the emergence of a real economy of Smart Cities. As we said before, the Smart City is a global and a complex process, not simply a technological issue.

Transforming an existing city into a Smart City is a long process that has to be very well planned. Depending on the extent of the change needed, it could easily take decades. As an example, the complete implementation of the Waterfront project in Toronto, a project totaling 1.5 Billion, is planned on a 30 years horizon. Such transformations always take time.

The golden rule in this domain involves a careful and coordinated planning, which goes beyond both partisanship and the desire to proceed too quickly. Since the total cost for such transformations may skyrocket, it also calls for a rigorous analysis of the real needs and priorities. It is therefore essential to analyse the situation carefully and plan in order to get a holistic vision and to use public funds wisely. Our city managers must choose the right infrastructures and services, those the citizens really need, as well as interoperable and agile systems. Furthermore, it is needed to keep managers up to date, to brief them on the real issues and benefits related to the recommended solutions regarding services to the community.

Those universities which are interested in the development and evolution of Smart Cities will surely take part in educating managers on new challenges and establishing new modes of governance. Their neutral position on these issues and their proximity to research centers, chairs and institutes from which innovations on Smart Cities emerge, make them good advisers to public management regarding such important technological and societal changes.

4.4. Need for standardization and reference frame for Smart Cities

The rapid growth of the Smart City concept and its adoption by communities in different continents is spectacular. Many communities have understood that this concept is a way to maintain attractiveness and prosperity.

We are witnessing a major shift in terms of global economic growth. Indeed, the GDP of western cities is decreasing, while that of major Asian cities (India and China) is increasing quickly [13]. If western cities want to maintain their leadership and to have leading economic activities, they will have to find new strategies to do so. The underlying philosophy for the Smart Cities transformations guarantees an increased attractiveness of brains and creative and innovative companies, more efficient organization and a concern with respect to the quality of life and sustainable development.

Concerns of different communities orient the directions of the Smart Cities' initiatives in the different countries and continents. Trend analysis of projects put forward by the Top 21 of the Intelligent Community Forum (ICF) and by the IBM Challenge on Smarter Cities highlighted the specifications and guidelines specific to different continents. As we pointed out before, in terms of guidance of Smart Cities, continents have different agendas. However, before the outbreak of the concept, steps are underway to the adoption of ISO norms to characterize the tag Smart Cities. In fact, the result of an international collective work on this issue will soon be published. The document was prepared by an international committee under the chairmanship of Patricia McCarney, professor at the University of Toronto. The proposed tittle of this document is *"Sustainable development and resilience of communities – Indicators for city services and quality of life."* [19]. We think that this guideline will be a useful tool to guide the reflection on the contribution of the digital transformation of cities, and help to avoid commercialization of "the Smart City" branding.

5. Conclusions

Geomatics is a key ingredient of Smart City development. With the forthcoming technological progresses, we can already envisioned increased capabilities in term of modeling urban environments at various scales, indoor and outdoor, above and underground and with a higher update rate. GeoBI technologies will provide a more complete picture of the operations and services at hand, and new knowledge and insight for use in city planning and management. However, geomatics involvement in Smart Cities should not be addressed from a technological standpoint only. Spatial intelligence demands spatial thinking abilities. This raises issues in term of spatial citizenship education that should be addressed in order for the Smart City to meet its accessibility, transparency and participation objectives.

The Smart City is a cultural change that eventually, if conducted in a serious and inclusive way, should create more civic (citizen-centered), attractive, prosperous and sustainable cities around the world. Seeing the Smart City model as broad as this is helping the concept to evolve and to lead to more civil and truly citizen-oriented cities, integrating cultural dimensions and paying attention to heritage. The evolution of the concept of Smart City should open to the concept of "sensible city" a city that uses technology, but to put people at the heart of the city, a concept used at the MIT Senseable LAB.[14] This enrichment of the concept of Smart City focuses on the human aspect rather than on technology. And necessarily if we focus on the human aspect, we will also necessarily take care of the quality of life, health, and the quality of the environment. And this leads us to the definition of Smart Cities and Communities proposed by the European Commission: that a smart city involves the economy of non-renewable resources, activities which promote a low global footprint leading to sustainability. A major part of theses objectives are enabled by the use of ICTs and especially Geomatics.

The Smart City concept, including the "sensible dimension" represents a real opportunity to rethink the city, to involve citizens, to ensure better governance, participatory and transparent, truly focused on the citizen, the economic development of the city and its sustainability.

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