SMART AND SUSTAINABLE NEIGHBORHOOD ASSESSMENT: INVESTIGATING THE HUMAN PERSPECTIVE OF SMART NEIGHBOURHOODS

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Keywords: smart city, assessment, behaviour, sustainability, neighbourhood, ICT-enabled

Abstract

Cities are becoming more complex and smart not only in terms of civil engineering infrastructures, ICT infrastructures but also in their socioeconomic systems. ICT technology enables to monitor, understand and analyse cities and neighbourhoods in multiple ways. Already, there are many performance indicators and data collection procedures to assess smart city solutions and projects. Only few focus on smart neighbourhoods and the socio-economic opportunities of smart urban developments.

This paper provides a strategic framework how smartness of neighbourhood scale urban developments could be assessed. The method proposes three levels to be considered. The first level evaluates the sustainability of the neighbourhood in traditional terms of the environmental, social and economic aspects. The second level addresses how the ICT systems enable urban development to become more sustainable. The third level adds the level of assessment of the citizens: how do they perceive the sustainable and ICT dimension of the neighbourhood. This new method of addressing the smart performance of neighbourhood can help decision-makers in selecting and clarifying the areas which need improvement and enables the development to constantly adapt to emerging socio-economic challenges.

1 Introduction

1.1 Importance of the topic

Since the first mention of the smart city in the 1990's, the vision has become popular not only among city leaders and citizens but among researchers. However, it is difficult to identify shared definitions and common trends at a global scale (Khansari et al, 2014), several study made an attempt to define the main dimensions and common characteristics of smart city concepts (Albino et al 2015; Neirotti et al 2014) and differentiate the meaning 'smart' from other terms used interchangeably to describe a liveable city (de Jong et al 2015). Based on previous studies it can be assumed that the optimization of available and new resources is an important part of smart urban development (Lazaroiu and Roscia 2012). However, it is clear that the limitations of hard infrastructure oriented strategies are now recognized and the concept of a smart city evolved to a socially inclusive direction (Mattoni et al 2015). It was revealed by many that technology in itself is not enough, as it does not imply that people will behave and act smart (Anthopoulos and Tougountzoglou 2012; Angelidou 2014). At the same time networked infrastructure and ICT technology that revises political efficiency and sustainable social/cultural development is often mentioned as a key element of being smart (Manville et al 2014) Social and human capital and interconnection between people and the city, as an enabler to creativity and innovation are also declared fundamental (Schaffers et al, 2011). Citizens have a key role in smart cities, based on the concept of Living Labs: are not only informed about their activities and their neighborhoods, but they became key player of shaping their cities (Cosgrave et al, 2013).

While the definition of smart cities is getting clearer, in practice city leaders are still strain to quantify the benefits that novel ICT can generate (Cosgrave et al, 2013). Although the social aspect gains emphasized attention in most smart city concepts, this aspect is the most difficult to measure (de Jong et al 2015). Moreover, assessment tools to address the smartness of any neighbourhood is still missing, despite of the fact that several neighbourhood sustainability assessment tools have been invented in the past decade to help the creation of sustainable, well-performing, liveable communities.

1.2 Research objectives

This paper explores whether an initiation of neighbourhood scale 'smart' assessment is useful to realize smart and sustainable urban development projects which can be scaled up to a city scale later on. The study also establishes a framework for such an assessment. In order to achieve this in the current research we assume that sustainability is a key to liveable and creative cities. We also suppose that data can improve the sustainable quality of neighbourhood developments from the better design of the building to the improved quality of life, as it can lead to behavioural change. Based on that, the hypothesis of the study is that neighbourhood scale assessment has the potential to quantify the benefits of smart initiatives of neighbourhoods both in terms of measuring the effects of implementing ICT technology and also, evaluating how citizens change their interactions and behaviour as an effect of advanced access to information.

1.3 Methodology

Understanding the potential value of neighbourhood scale smart assessments requires a comprehension of constraints in city scale smart city projects and the replicability limitation of any smart initiative. It is also necessary to learn how sustainability aspects are integrated in realized and ongoing smart city projects and vice versa: how sustainable urban development projects use smart technology. Therefore, we have undertaken a literature review of the scalability and sustainability prospects in smart city concepts. We have also studied the presence of digital layer among smart city indicators in order to identify whether and how ICT can be used to measure improvements in the sustainability level of the project. As citizens play an active role in smart initiatives an analysis has been performed focusing on how people make their choices, how changes in behavioural outcomes can be measured.

On the basis of the research we formulated a framework for an assessment which considers sustainability, the effect of ICT use, participation and behavioural change on the same page.

2 Scale of smart initiatives

Studies often define that smart city initiatives have the unintended potential to grow social disparities among the population by digitally dividing the people (Chourabi et al 2012; Angelidou 2014). It means increased inequality and not equal accessibility to ICT technology. In other terms smart city has the possibility to fail to provide accessibility to different smart assets for all citizens, e.g. in Rio de Janiero (Angelidou 2014). It implies that the 'smartness' of a city cannot be assessed based on certain smart city projects implemented in the city as they do not necessarily affect the whole city. Moreover, large size has potential to have more barriers to smart cities, e.g. longer installation times for smart technologies (Neirotti et al 2014).

Manville et al (2014) have performed an analysis of existing smart city projects in Europe. They stated that smart city projects differ greatly in their size, scalability and maturity level. This heterogeneity makes the comparison of smart city project difficult; moreover, their relative immaturity renders the assessment of the success factor really hard at city level. For the purpose of Manville's study to identify how auspicious any given project is: different smart initiatives were grouped in five main categories. These were the following: Smart City Neighbourhood Units; Testbed Micro Infrastructures; Intelligent Traffic Systems; Resource Management Systems and Participation Platforms. The research While Intelligent Traffic Systems; Participation Platforms, Testbed Microinfrstuctures are likely to address certain dimensions of a smart city; Smart Neighborhoods could cover more evenly the smart dimensions, namely: Smart Environment, Smart Mobility, Smart Economy, Smart People, Smart Living, the only dimension which has not been addressed is Smart Governance. Smart Neighbourhoods have the capability to identify 'good practice', on the other hand, the solution implemented in Smart Neighbourhoods is likely to be site-specific, hence with limited replicability potential. The scaling up potential of testbed micro infrastructures and intelligent traffic systems are the highest. Testbed Micro Infrastructures are demonstration and testing pilots in real-life context used to understand and study how to integrate, manage and monitor the behaviour of implemented technology, so as connect as many things as possible, in the sense of the 'Internet of Things' (Manville et al, 2014).

Local context is really important in case of smart initiatives: the success of smart city strategies depends greatly on the local socio-economic and cultural background (Neirotti et al 2014). Moreover, most research on low-carbon communities focus on geographically local communities which have place-based identity, shared history, shared infrastructure, and political and administrative power (Heiskanen et al 2010). In that sense neighbourhood level communities have place-based identity, common history and infrastructure and they are embedded in a given political and administrative context of their city. In order to transition to low carbon communities a change is required in social practices, norms and values. As a range of technological solutions are not accommodated in the social context, they have not resulted in the expected energy efficiency gains. Local communities are more likely to approach change towards a low carbon life, as their approach is suited to local contexts, therefore can address more appropriately change in the social practice (Moloney et al 2010).

According to Gardner and Stern (1996), one of instruments to change behaviour in relation to environmental problems is community management of environmental resources. It is also pointed out by Mancha and Yoder (2015) that people's intended behaviours are strongly influenced by perceived social pressures. Therefore, strategies aiming to increase awareness of green social norms could more efficiently shape behaviour. Nonetheless, urban designers currently have no comprehensive measurement tool to quantify the interconnections that take place at neighbourhood developments and procedures to have feedback during the design process to see the consequences of their decisions (Frenchman et al 2011)

3 Layers of smartness based on current literature

3.1 Sustainability prospects in smart city concepts

According to de Yong's comprehensive bibliometric analysis (2015) smart city concepts becoming important drivers of urban sustainability and regeneration initiatives. The assurance of social and economic aspects of sustainability- which originates in the Smart Growth Movement, in the late 1990s- is often referred as the key role of smart cities. Connection between environmental and ecological sustainability is weaker, most definitions of smart city do not concern ecological sustainability (Kramers et al 2014). In the same study, Kramer et al suggested the use of the terms: "smart sustainable cities", referring to smart cities that promote environmental sustainability as well. We use the same terms in this paper considering smart urban developments that address all three pillars of sustainability.

However Smart City has been more about liveable, creative, digital and knowledge-based cities (Marsal-Llacuna et al, 2015), the pursuit of sustainability –not only in terms of social and economic sustainability, but in terms of environmental sustainability- is getting to be an important element of smart city definitions (Barrionuevo et al. 2012; Bakici et al. 2012; Ballas 2013, Albino et al 2015). The examination of the analyzed Smart Neighbourhoods in the study of *Mapping Smart Cities in the EU* reveals that environmental aspects are well represented in them. Reduced energy consumption, the integration of smart meters and grids, the use of renewable energy, effective water and waste management systems and efficient public transport system frequently appear in the projects. Besides the environmental objectives, the projects emphasize Smart Living, the dimension to enhancing residents' quality of life (Manville et al 2014). In MIT's study of clean energy communities also reveals social aspects of sustainability: it states that successful clean energy projects include feedback mechanisms or other programs to commit citizens in their ambition of energy saving. Moreover, they support the formation of strong communities where residents are more likely to modify their energy behaviour (Frenchman and Zegras, 2012).

3.2 ICT as an enabler to smart sustainable cities

Smart city concepts are often attached with the idea of a digital platform and the use of ICT (Bakici et al., 2012; Jucevicius et al., 2014, Caragliu et al., 2009) .which serves as digital nervous system that obtains data from heterogeneous sources (Neirotti et al, 2014). Jucevicius et al. (2014) has examined the impact of various digital systems on the 'smartness' of the city. They established a set of indicators strongly related to digital dimension and conducted a research how well these indicators are represented in various studies. It has been affirmed that digitalism does not dominate in any of the main features among smart city categories, but it is important to all of them and underlies all characteristics. In other studies, the opportunities of using ICT as an enabling technology to reduce energy use in cities has been analyzed (Kramers et al 2014; GeSI, 2008). ICT has capability to help forming more sustainable cities through *dematerialization* - conversion of physical products to digital ones-, demobilization - transportation via the telecoms network instead of being physically transportation-, *mass customization* - use of less resource use because of the adaptation and personalization potential of ICT- *intelligent operation* - resource-efficient operation- and *soft transformation* - transform because of new opportunities (Mitchell 2000, Kramers et al 2014). The study of Kramers et al (2014) differentiated two types of ICT solutions: the ones with a direct effect on energy consumption and the ones which are ICT enabled and have indirect effect. The research states that energy reduction opportunity has not yet been realized to its greatest extent (Kramers et al 2014), however the influence of ICT by enabling energy efficiencies in other sectors is predicted to deliver carbon savings five times larger than the total emissions from the entire ICT sector in 2020.(GeSI, 2008).

ICT enabled smart initiatives are strongly associated with the use of Internet of Things (IoT). Internet of things is integration of various technology and communications solutions. The IoT is the concept of a global, network infrastructure where physical and virtual "things" (devices, sensors, smart objects, etc.) communicate and share information among each other dynamically (Silva and Maló, 2014). Among others it means the "*Identification and tracking technologies, wired and wireless sensor and actuator networks, enhanced communication protocols and distributed intelligence for smart objects*" (Atzori et al 2010). Potentialities offered by the IoT make the development of a huge number of applications possible in domains such as *Transportation and logistics, Monitoring of industrial plants, Healthcare, Emergency, Smart environment (home, office, plant)*

domain, Personal and social domain. IoT integrates several enabling technologies, such as RFID systems, wireless sensor networks, RFID sensor networks, Smart meters, GPS terminals etc. (Atzori et al 2010, Borgia, 2014).

3.3 Examination of citizens, behavioural aspects

The social learning theory of Bandura (1977) finds out that learning is a cognitive process and it changes through the social context. Most behaviour lead to consequences which will impact the future behaviour: either maintaining or changing it (Khansari et al, 2014). Based on the idea of Coe et al (2001) smart city is the place, where behavioural change can occur: it is "*A city whose community has learned to learn, adapt and innovate*". Soft infrastructure and people-oriented smart city concepts are strongly based on these theories: the promise of a smart city is - among others- that it can foster behavioural change towards a more sustainable lifestyle (Angelidou, 2014, ARUP 1999). The service innovation of smart city allows insight into provides real-time information on the performance of systems and resource consumption, additionally insight into citizens' behaviour in order to recognize, study and act on those patterns (Frenchman et al. 2011).This does not only mean a highly instrumented top-down method: such real-time engagement can change people's energy behaviour (Darby, 2006), feedback data allows citizens to alter their actions accordingly while making better use of the resources (Khansari et al, 2014). The investment in human and social capital is essential to be smart and sustain the economic growth and a high quality of life (Caragliu et al. 2009). Smart Neighbourhoods strongly rely on citizens; they are the ones who can enliven the smart technology. The commitment of the stakeholders is essential, without them, the data available can't shape a smart city. Therefore, citizens should be engaged through a participative environment to contribute to and create smart neighbourhoods (Manville et al. 2014).

The idea of Internet of Things has a high impact on several aspects of everyday-life and the behaviour of potential users (Atzori et al. 2010). Moreover, on the basis of *Information Marketplaces* concept: city can be used as a real-world testing ground for new ideas and technologies where users are transforming from passive recipients of ideas, services and solutions to active generators and creators of the their smart city. The value chain perspective is necessary to obtain full value from their ICT investments, where real-time data inputs (e.g. number of passengers, journey time etc.) serve as a base for gathering information components (e.g. usage patterns of public transport system) which then generate information products (e.g. feedback to improve public transport). *Living Lab* has the infrastructure to provide a vast amount of data as inputs into this new value chain (Cosgrave et al, 2013). The development of a digital platform is important in order to have a smart social system, however many social systems can be smart without necessarily basing their activities on Information and Communication Technologies (Jucevičius et al. 2014).

Based on the above it is evident that citizens are inevitable to create positive impact in the smart urban environment and make data to be a value. However, it is addressed by only a few, how the evidence of this value should be measured. Priano and Guerra (2014) defined an N-dimensional framework where each dimension of the smart city can be evaluated independently. Amongst others they stated that even though cities implement smart solutions and services, the actual level of smartness is valued by the residents, and measures that evaluate smartness should be representative of the entire city. Therefore, they included the assessment of the citizens in the overall framework which is a complementary part of the evaluation. This is in line with the estimation that only 5% of the available digital information is currently being used (Marsal-Llacuna et al. 2015). Carli et al (2013) also outlined a human centric framework to access smart cities. Besides the fact that they categorize indicators based on the degree of objectivity, they state that the level of technological advancement of data extraction is also an important characteristic to evaluate an indicator. For example, indicators with a high degree of subjectivity can be derived either from traditional repositories such as surveys and questionnaires, or extracted from innovative tools based on data sensing and mining of the physical and social infrastructure, e.g. complex analyzes of user generated data such as web based reviews, ratings and recommendations.

4 Results

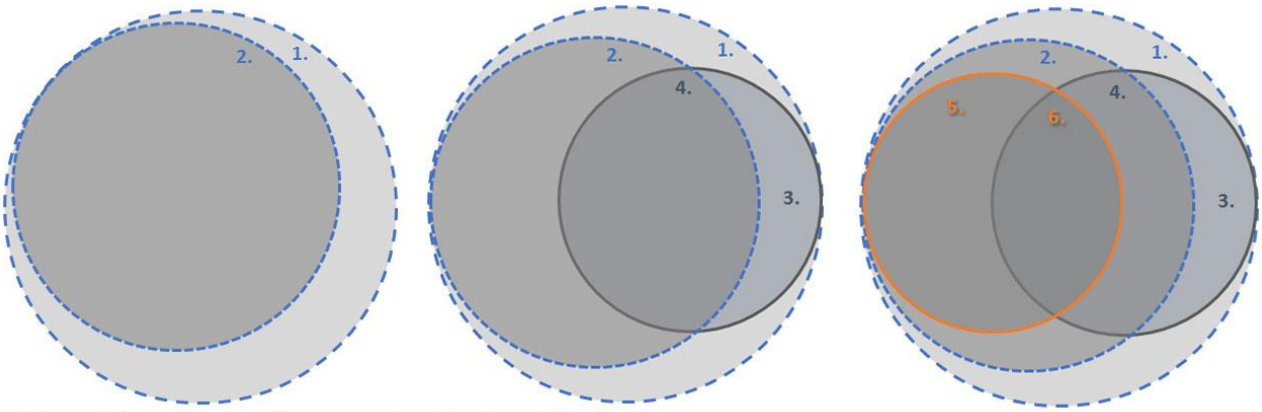
Neighbourhood scale smart initiatives could describe more extensively the attributes of the smart city, with less potential for scaling up. However, there are smart city project types with higher replicability potential. One of Test-bed microinfrastructures has to capability to be combined with Smart neighbourhoods, as they are not place-based. Test-bed microinfrastructures strongly emphasize the use of Internet of Things (IoT). The implementation of IoT at neighbourhood scale assessment could have the capability to measure the effects of implementing a given information technology and give feedback on citizens behaviour, and vice versa provides information to the user to enable their behaviour change. Besides the fact that neighbourhood scale developments have the potential to form communities, as these developments are greatly embodied in the local socio-economic context; from an energy consumption viewpoint: they can also reveal interrelationships of urban form and the behavioural component of neighbourhood energy consumption. Links between multiple

buildings and citizens, plus synergies and compromise generated as a result of interaction in the urban context, can be introduced. Examining the analyzed Smart Neighbourhood projects in the study of Manville et al (2014) (London suburb of Hackbridge, UK; Hafencity in Hamburg, Germany; Nordhavn in Copenhagen, Denmark; Stockholm Royal Seaport, Sweden; Oulu Arctic City; Finland), revealed that none of the them had a developed smart assessment scheme to address the smartness of the development. It is not evaluated whether ICT is used to measure improvements in the sustainability level of the project and whether the change of behaviour or feedback on the implementation of any measure is addressed. However, they are just in the planning or development stage.

The literature review revealed that sustainability is a comprehensive base for smart city initiatives. Social and economic sustainability is more featured in smart city projects in general. At the same time, the need to acknowledge the environmental pillar of sustainability is remarked in addition in neighbourhood scale smart city projects, the environmental aspects are more significant. Therefore, the realization of sustainability as a whole should be assessed when the smartness of any neighbourhood is examined and it should provide a base for any smart neighbourhood evaluation. Therefore, if a neighbourhood aims to be smart, measures taken to reach that goal should be based on the principles of sustainability. Based on different smart city definitions it turned out that smart cities strongly rest on networked infrastructure and ICT. Smart city projects which have strong sustainability ambitions should seek to understand how to utilize best potentials offered by ICT and how to measure its actual impact, which is not necessarily positive (rebound effect). For the successful delivery of ICT investments, it is necessary utilize them to the fullest and create value from the data set they can provide. *Living Lab* has the supply network to support the understanding of value beyond the optimisation of systems. Based on that, smart neighbourhoods should have ICT based tools and procedures to realize smartness. The current study also shows the relevance of citizens in successful smart city initiatives. It also emphasizes that interconnection between people and the city is significant. Accordingly, smart neighbourhoods should have a mechanism that enables participation and behaviour change. These instruments can be partially ICT-based, as Information and Communications Technologies are implemented either to reach higher efficiency in the hard infrastructure or optimize the soft infrastructure of the city.

5 Proposed layers of smart neighbourhoods based on the literature review

With reference to the above mentioned the current study proposes that smart sustainable neighbourhoods have the following layers: they are established on measures implemented to gain sustainability (Figure 1, set 1 and 2), part of these measures is ICT based, or ICT enabled tools (Figure 1, set 3 and 4). Behaviour change and the inclusion of citizens form the third layer of smart sustainable neighbourhoods (Figure 1, set 5 and 6). Potential measure is differentiated from the realized ones. In that sense, smart neighbourhoods are the ones represented under set 4, 5 and 6. They have to be based on sustainability, and which can be gained with the implementation of ICT or it can lead to behavioural change and higher involvement of the citizens.

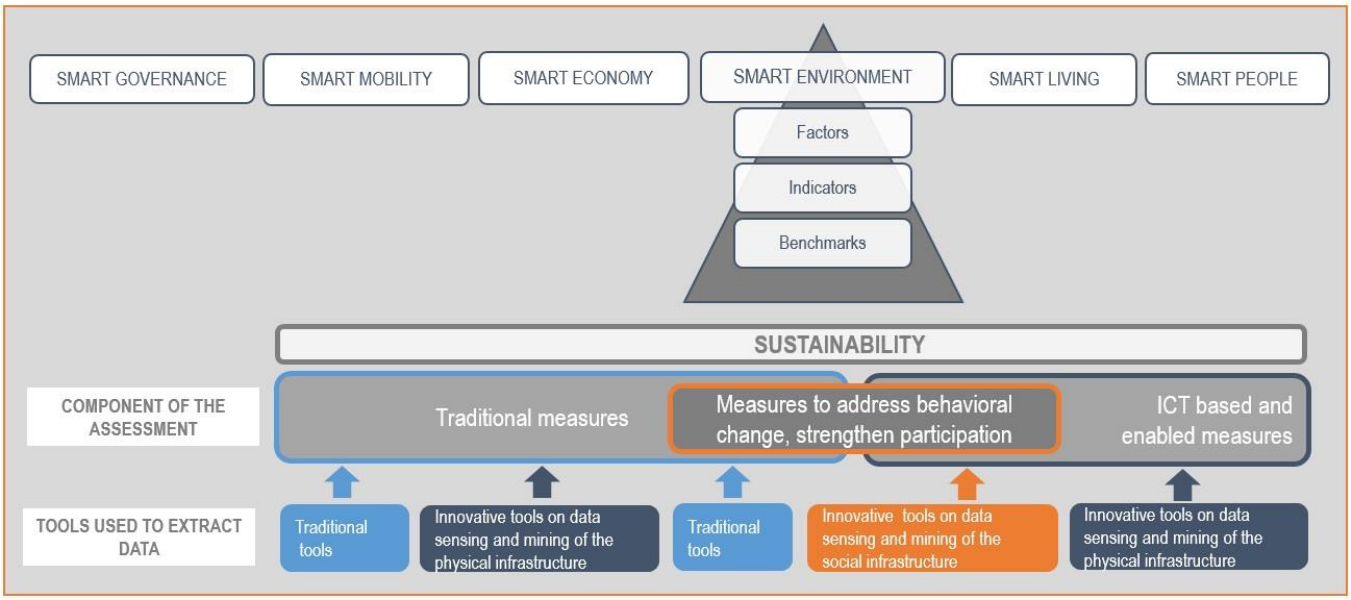


1. Potential measures to achieve a smart sustainable neighborhood
2. Realized measures to achieve smart sustainable neighborhood
3. Potential ICT measures (direct and ICT enabled indirect)
4. Realized ICT measures
5. Measures that enable participation, behaviour change
6. Realized ICT measures that enable participation, behaviour change

1. Figure: Proposed layers of smart neighbourhoods based on the literature review

6 Framework for Smart Sustainable Neighbourhood Assessment

The determination of smart qualities of urban developments in order to define a framework for smart sustainable neighbourhood assessment has been a critical challenge. The above mentioned layers provide an outline for such methodological framework. It also has been showed that there is a gap in the plateau of smart assessment schemes, as they focus on city scale; while neighbourhood assessments concentrate on sustainability aspects. Furthermore, technology innovation must have a clear evidence of the value of its application: the effects of implementing ICT and ICT enabled technology should be measured. Even though social aspects are an essential part of most smart city definition, there is no framework to evaluate how citizens change their interactions and behaviour, as a result of advanced access to information and implemented sustainability measure. Based on that, there is a potential in developing a Smart Neighbourhood Assessment scheme which could have the possibility to describe smartness gained by all of the citizens in the analyzed neighbourhood, have the capability to compare different smart neighbourhoods and builds up a model with soft and hard infrastructure.



2. Figure Methodological framework

The methodological framework (2. Figure) that we propose reflects the different layers of being smart defined above. It uses the certain aspects from various studies: Priano and Guerra 2014; Carli et al 2013; Giffinger et al 2007. The first level of the assessment is the evaluation how sustainable the neighbourhood is. Sustainability can be gained by several ways. One option is implementing traditional tools, such as passive design measures and energy efficient mechanical systems to gain environmental sustainability or applying regulations that provide equal rights to citizens in order to assure social sustainability etc. The first layer of the assessment represents these measures. The impact of traditional assets can be evaluated either with traditional tools (e.g. statistical data describing life expectancy) or innovative tools on data sensing and mining of the physical infrastructure (e.g. data extracted from smart grids). The utilization of Information and Communication Technology can also contribute to sustainability e.g. smart metering can help resource efficiency or internet can provide access to data. The second layer represents ICT based tools and protocols. This layer can describe both ICT measures in itself or technologies that are enabled with ICT such as car-sharing. Therefore, the assessment of this layer is based on innovative tool on data sensing and mining of the physical infrastructure as all measures can be evaluated with ICT. The assessment of the people is the third layer; it reflects the human perception of actions taken. It measures the change in citizens' behaviour to a more sustainable one, so as the involvement of the people in the design, operation of the neighbourhood. Data can be extracted by traditional tools, such as questionnaire about occupant behaviour, or data can be gathered with the help of ICT, for example data mining from social media platforms. The framework preserves the classical dimensions of smart cities (Smart Living, Smart People, Smart Environment, Smart Government, Smart Economy, and Smart Mobility). These characteristic can be determined by a number of factors. Furthermore, each factor is described by a number of indicators. Indicators can evaluate by benchmarks. The different measures are used to fulfil the benchmarks and different tools can be used to measure the performance of different measures.

7 Conclusions

The concept of a smart city has been named as both a challenge and an opportunity for cities (ARUP, 1999). This study emphasizes that in case of a neighbourhood development a transparent and uniform methodology should be developed to address the smart dimensions of a neighbourhood and help to explore these challenges and opportunities. In the paper a framework has been presented for assessing smartness of neighbourhood developments on a theoretical approach. This framework brings together a large number of previous studies into one methodology, including researches approached to define smart cities at conceptual level and smart city ranking and evaluating schemes. Moreover, the study is enforced with literature review of how sustainability, ICT and behavioural aspects are embedded in smart city initiatives. This methodological framework addresses the smart qualities that current cities should have: it should satisfy sustainable development, include ICT in the life-cycle of a development and facilitate awareness driven change in the behaviours of citizens. With the support of the framework potential solutions and projects can be compared to decide which ones offer the best results for neighbourhood.

In the future specific factors, indicators, benchmarks, measures and evaluation tools of the methodology have to be fully investigated. Subsequently, it has to be considered that different cities have different needs and face unique challenges. Therefore, the proportion of traditional and ICT-based measure can be different, and even the solutions to evaluate the measures can be specific. Future work is planned to perform experiments on these ideas by implementing the framework on existing territorial contexts and on different state of the Integrated design process.

8 Acknowledgments

The basis of this research has been outlined during an exchange project, supported by the European Institute for Innovation and Technology “EIT Grant Funding”, in the framework of Climate KIC 'Pioneers into Practice Program 2015'. The authors gratefully acknowledge the generous support of ABUD Engineering Ltd.

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