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What are the differences between sustainable and smart cities?

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ABSTRACT

City assessment tools can be used as support for decision making in urban development as they provide assessment methodologies for cities to show the progress towards defined targets. In the 21st century, there has been a shift from sustainability assessment to smart city goals. We analyze 16 sets of city assessment frameworks (eight smart city and eight urban sustainability assessment frameworks) comprising 958 indicators altogether by dividing the indicators under three impact categories and 12 sectors. The following main observations derive from the analyses: as expected, there is a much stronger focus on modern technologies and "smartness" in the smart city frameworks compared to urban sustainability frameworks. Another observation is that as urban sustainability frameworks contain a large number of indicators measuring environmental sustainability, smart city frameworks lack environmental indicators while highlighting social and economic aspects. A general goal of smart cities is to improve sustainability with help of technologies. Thus, we recommend the use of a more accurate term "smart sustainable cities" instead of smart cities. However, the current large gap between smart city and sustainable city frameworks suggest that there is a need for developing smart city frameworks further or re-defining the smart city concept. We recommend that the assessment of smart city performance should not only use output indicators that measure the efficiency of deployment of smart solutions but also impact indicators that measure the contribution towards the ultimate goals such as environmental, economic or social sustainability.

1. Introduction

According to an estimate by the United Nations, by 2050 66% of the world's population will live in urban areas (United Nations, 2015a) giving rise to extensive challenges regarding air pollution, congestion, waste management and human health (OECD, 2012). As the European Union (European Commission, 2014) and United Nations (2016) have set ambitious climate and energy targets for the coming years, there is an urgent need to develop smart solutions to overcome the challenges of urbanization.

Cities have a key role in fighting against climate change and the deployment of new intelligent technologies is seen as key factor in decreasing greenhouse gas emissions and improving energy efficiency of cities. These technologies need to be smart, lean, integrated, cost-efficient and resource-efficient, and they should have an impact not only on environmental sustainability targets but also on citizens' wellbeing and financial sustainability.

In recent years, there has been a shift in cities striving for smart city targets instead of sustainability goals (Marsal-Llacuna, Colomer-Llinàs, & Meléndez-Frigola, 2015). However, these are interconnected and often smart cities share similar goals as sustainable cities. A large variety of smart city definitions exist (Albino, Berardi, & Dangelico, 2015) and not all definitions reflect their relation with the sustainability targets. Hence, there is a need to better understand the relation of the smart and sustainable city concepts (Bifulco, Tregua, Amitrano, & D'Auria, 2016).

In European Union's (2011) view the smart city concept supports the idea of environmental sustainability as its main aim is reducing greenhouse gas emissions in urban areas through the deployment of innovative technologies. The growing interest in the smart city concept and the needs to solve the challenges related to urbanization lead to several private and public investments in the technology development and deployment. This can be seen in the high number of smart city initiatives, city implementation projects and jointly-funded public research projects. In 2012 there were 143 ongoing smart city projects of which 47 were located in Europe and 30 in the USA (Lee & Hancock, 2012). Cities have also been setting high targets for a clean future by taking part in initiatives and city networks such as Covenant of Mayors (Covenant of Mayors), CIVITAS (CIVITAS), CONCERTO (CONCERTO) and Green Digital Charter (Green Digital Charter). These were established to support the striving for the ambitious energy efficiency and CO_2 reduction targets such as the European Union 2030 targets. Tools are needed

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to help the decision makers to take actions towards the wanted direction, derive these to the operational level and to assess cities' progress in pursuing these targets. Therefore, several frameworks have been developed to assess urban performance, some focusing on urban sustainability and others more on the smart cities technologies itself.

The aim of this study is to develop understanding of the similarities and differences between the sustainable and smart cities concepts and respective assessment frameworks. To do so, eight existing sustainable and smart city performance measurement systems were compared with regard to the application domains and impact categories of the indicators used.

1.1. Urban sustainability

In our study we compare smart city assessment frameworks with urban sustainability frameworks and therefore a brief review on the development of these two types of urban assessment is given.

In line with the original definition of sustainable development (WCED, 1987), a city can be defined to be sustainable "if its conditions of production do not destroy over time the conditions of its reproduction" (Castells, 2000). More recently, Hiremath, Balachandra, Kumar, Bansode, and Murali (2013) have characterized urban sustainable development as "achieving a balance between the development of the urban areas and protection of the environment with an eye to equity in income, employment, shelter, basic services, social infrastructure and transportation in the urban areas". A large number of environmental assessment tools and frameworks have been developed for the building sector to help political decision making and to ensure that with the measures taken the built environment sector as well as transport is moving towards sustainability goals. Recently there has been a change in the focus and instead of single buildings the targets of assessment now consist of neighborhoods and districts enabling the simultaneous consideration of built environment, public transportation and services, among others (Haapio, 2012).

According to Marsal-Llacuna et al. (2015) urban monitoring started in the 1990s when the Local Agenda 21 (United Nations, 1992) established indicators to monitor sustainability of urban areas. Quality of life aspects with respective indicators appeared in the following decade, initiated by Mercer's annual quality of life survey (Mercer, 2014) and the Economist Intelligence Unit's quality of life index (Economist Intelligence Unit, 2005). The livable city concept has further been presented by at least two well-known rankings by media companies: Monocle's Most Livable City (Monocle, 2014) ranking and International Living's Quality of Life Index (International Living, 2014).

McManus (2012) presents that urban sustainability indicators are produced by three types of organizations: environmental organizations, organizations promoting green citizenship and sustainable capitalism and consultancy organizations. The tools that have been developed are either sustainable city rankings or tools that allow cities to compare best solutions and find best practices. A number of indicator systems have also been developed by research organizations and research projects. According to Tanguay, Rajaonson, Lefebvre, and Lanoie (2010) sustainable development indicators are increasingly used by public administration in order to confirm cities' sustainable development strategies especially by enabling assessment and monitoring activities. However, as Huang, Yeh, Budd, and Chen (2009) remark, there are limitations with the use of sustainability indicators as they neither reflect systemic interactions, nor provide normative indications on the direction to be followed.

Diverse urban sustainability assessment tools approach sustainability from different angles. Well-known neighborhood sustainability rating tools, such as LEED, BREEAM and CASBEE, analyzed for example by Sharifi and Murayama (2013), aim at labelling. On the other hand, Hedman, Sepponen, and Virtanen (2014) present a tool which was developed to help city planners to assess the energy efficiency of a detailed city plan, by analyzing the energy demand of buildings and transportation as well as the energy system and source of energy. In addition, transportation has been the focus of several assessment frameworks, developed particularly for densely populated Asian cities, such as the Partnership for Sustainable Urban Transport in Asia (PSUTA) (CAI-Asia Program) and the Bangalore Mobility Indicators (Directorate of Urban Land Transport, 2011). The versatility of different approaches can however be seen as a problem when looking for a holistic assessment framework for steering integrated challenges. As Tanguay et al. (2010) suggest, "the absence of a less general and more universal definition of sustainable development has given rise to multiple interpretations and in particular has triggered an explosion of indicators".

Even though sustainability is typically characterized by simultaneous consideration of economic, environmental and social impacts, the existing assessment tools usually have a strong environmental focus (Berardi, 2013; Robinson & Cole, 2015; Tanguay et al., 2010). For example, the most well-known sustainable neighborhood rating schemes BREEAM, CASBEE and LEED assign very low weight to direct economic and social measures (on average 3% for business and economy and 5% for well-being) (Berardi, 2013). Moreover, the so called "green" or "sustainable" design approaches have been criticized to only focus on reducing the pace of doing harm to the environment (Cole, 2012; Reed, 2007), and therefore the more integrative and holistic term of "regenerative sustainability" has been suggested instead (Robinson & Cole, 2015). As most of the sustainability assessment tools have been developed top-down by expert organizations, many scholars (Berardi, 2013; Reed, Fraser, & Dougill, 2006; Robinson & Cole, 2015; Turcu, 2013) have called for the integration of citizen-led, participatory, localized and procedural approaches.

In order to properly address the interactions between the different aspects of a city a systemic approach is needed. Cities need to be understood as urban ecosystems that are composed of interactions between the social, biological and physical components (Nilon, Berkowitz, & Hollweg, 2003). The understanding of the relationships between people, their activities and the environment is key to achieve sustainability. Urban morphology studies the spatial structures and character of a city. The spatial distribution of activities and accessibility of different services – especially urban forms, functions and their connections – are crucial aspects of a sustainable city that uses its resources most efficiently (Bourdic, Salat, & Nowacki, 2012; Salat & Bourdic, 2012).

1.2. The smart city concept

The concept "smart city" was introduced already in 1994 (Dameri & Cocchia, 2013) and since 2010, after the appearance of smart city projects and support by the EU, the number of publications regarding the topic has considerably increased (Jucevicius, Patašienė, & Patašius, 2014). While this concept is widely used today there is still not a clear and consistent understanding of its meaning (Angelidou, 2015; Chourabi et al., 2012; Caragliu, Del Bo, & Nijkamp, 2011; Hollands, 2008; Marsal-Llacuna et al., 2015; Wall & Stravlopoulos, 2016). A common understanding, also shared by the European Commission, is that diverse technologies help in achieving sustainability in smart cities (European Commission, 2012). According to the latter source, smart cities and communities focus on the intersection between energy, transport and ICT, which are also the fields that have received most of the EU's public smart cities related funding (under the Horizon 2020 program "smart cities and communities"). Marsal-Llacuna et al. (2015) present that the smart city assessment builds on "the previous experiences of measuring environmentally friendly and livable cities, embracing the concepts of sustainability and quality of life but with the important and significant addition of technological and informational components". Even if both policy makers and academia have recognized the use of modern technologies as an inseparable aspect of smart cities, a great number of definitions with slightly different angles have been provided.

The literature which highlights the use of ICT and modern technologies as a key to a smart city is extensive (Gonzales & Rossi, 2011; Harrison & Donnely, 2011; Hung-Nien, Chiu-Yao, Chung-Chih, & Yuan-Yu, 2011; Jucevicius et al., 2014; Paroutis, Bennett, & Heracleous, 2013; Washburn et al., 2010). One part of the smart city literature focuses mainly on technical and environmental aspects of a city. According to Lombardi et al. (2011) several smart city definitions emphasize the use of modern technologies in everyday urban life resulting in innovative transport systems, infrastructures, logistics and green and efficient energy systems. A broader understanding of smart cities also highlights the use of modern technologies but sees them more as an enabler for better quality of life and decreased environmental impacts (IEEE, 2014). As an example, Marsal-Llacuna et al. (2015) suggest that smart city initiatives aim, by using data and information technologies, to "provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration amongst different economic actors and to encourage innovative business models in both private and public sectors." On the other hand, the definition of Angelidou (2014) highlights the role of ICT to achieve prosperity, effectiveness and competitiveness.

Another body of literature highlights – in addition to new technologies – the role of human capital in developing smart cities with improved economic, social and environmental sustainability (Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014; Giffinger et al., 2007; Hollands, 2008; Nam & Pardo, 2011). This more holistic understanding suggests that smart cities bring together technology, government and society to enable a smart economy, smart mobility, smart environment, smart people, smart living and smart governance (IEEE, 2014). As an example of this approach, Caragliu et al. (2011) present that a city is smart "when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance". Lombardi et al. (2011) mention participation, security/safety and cultural heritage as additional "soft factors" considered in smart cities. Also, according to a definition by Correia and Wünstel (2011) a smart city is "able to link physical capital with social one, and to develop better services and infrastructure". Services are also given importance to by Belanche, Casaló, & Orús, 2016 and Lee, Hancock, and Hu (2014). Belanche et al. (2016) highlight the role of city attachment and attitudes for increased use of urban services to achieve efficiency and sustainability in smart cities while Lee et al. (2014) emphasize the role of participatory service design and open data movement in smart city development. The authors also mention the deployment of intelligent infrastructure, a robust incentive system and centralized governance as ways to accelerate smart city adoption. Finally, the Joint Programme on Smart Cities by the European Energy Research Alliance (EERA) highlights the environmental sustainability aspects of smart cities suggesting that smart cities are "expected to move the energy system towards a more sustainable path. This will require an integrated systems view as well as innovative, intelligent approaches to the design and operation of urban energy systems." (EERA Joint Programme on Smart Cities, 2013).

In essence, it can be summarized that there are two mainstreams in the present smart city discussion: 1) the ICT and technology oriented approach and 2) the people oriented approach. Angelidou (2014) calls this a dimension of smart cities ranging from strategies that target the efficiency and technological advancement of the city's hard infrastructures (i.e. transport, water, waste, energy) to those focusing on the soft infrastructure and people (i.e. social and human capital, knowledge, inclusion, participation, social innovation and equity). Other metaphors used to categorize smart city views are top-down vs. bottom-up initiatives (Calzada & Cobo, 2015) and supply vs. demand driven approaches (Angelidou, 2015).

Frameworks such as the Smart Cities Wheel (Boyd Cohen) and the European Smart Cities Ranking (Giffinger et al., 2007) have been developed to enable the comparison of cities and to assess cities' development towards the wanted direction. Other smart city performance assessment systems have been presented for example by Albino et al. (2015), Lazaroiu and Roscia (2012) and Lombardi, Giordano, Farouh, and Yousef (2012). Specific frameworks and indicators to benchmark cities according to the smartness of their transportation systems have been proposed by Debnath, Chin, Haque, and Yuen (2014) and Garau, Masala, and Pinna (2016). For example Garau, Masala, and Pinna (2015) provide a valid methodology for cities to assess the smartness of urban mobility, and use this method to benchmark 17 Italian cities.

2. Material and methods

2.1. The chosen smart city and urban sustainability assessment frameworks

To study the smart city performance measurement systems and targets we selected a set of smart city assessment frameworks for the analysis. In addition, for comparing how smart cities differ from sustainable cities, we selected the same number of urban sustainability frameworks for the study.

Because of the great variety of definitions of the smart city concept it was challenging to decide which smart city frameworks/rankings should be considered in the analysis. The frameworks were finally selected by using three criteria: 1) the framework should clearly state that it is measuring *smartness*; 2) enough detailed level information about indicators and methods had to be available, and 3) the framework should cover several areas of city functions (not only transport or energy, for example). By using these criteria, eight smart city frameworks were chosen (see Table 1).

Selecting a set of urban sustainability frameworks was even more challenging because of the tremendous number of existing performance measurement systems. The ones which were chosen for our study are widely used and well-known. The same selection criteria, defined above, were used (replacing 'measuring smartness' with 'measuring urban sustainability'). To enable comparison of the two types of assessment frameworks, we wanted to keep the number of urban sustainability frameworks also at eight (see Table 2). For both types of frameworks, we did include whenever possible, assessment systems covering a large geographical area (Europe, North America, Asia).

The analysis is based on a literature review of the existing performance measurement systems and the used sources comprise both scientific and non-scientific sources, such as technical manuals and websites (in case no scientific publications were available).

2.2. Method and data

Indicators are figures or other measures that enable information on a complex phenomenon such as environmental impact to be simplified into a form that is relatively easy to use and understand. The three main functions of indicators are quantification, simplification and communication (ISO, 2010) Cities need indicators to set targets and track and monitor progress on performance (ISO, 2014). As Tanguay et al. (2010) presents, it is essential to clarify the difference between *data*/a *variable* and an *indicator*. Data/variable becomes an indicator only when its role in the evaluation of a phenomenon has been established, meaning that the changes of the data or variable have been defined as negative or positive. Different types of indicators can be categorized in several ways. Performance indicators measure the required end performance instead of prescribing the technical solutions to achieve that performance (Gibson, 1982). The latter can be called prescriptive indicators. Another more detailed categorization is to group indicators based on whether they measure inputs, outputs, outcomes or impacts (Segnestam, 2002).

Weighting is sometimes part of the assessment frameworks. Indicators may be given weights, which means that a certain indicator is given higher or lower value or contribution to the result than another

Table 1
The smart city frameworks/rankings considered in the study.

Name of the framework	Description	Source	Number of	
			Categories	Indicators
European Smart Cities Ranking	A European ranking elaborated and published by an international consortium headed by the University of Technology Vienna.	Giffinger et al. (2007)	6	64
The Smart Cities Wheel	An international holistic framework for considering all key components of what makes a city smart and to support smart city benchmarking. Developed by Boyd Cohen in collaboration with Buenos Aires, Barcelona and other leading cities around the globe.	Boyd Cohen	6	26
Bilbao Smart Cities Study	A study initiated in the Bilbao World Summit, giving an overview of the current situation of cities in different regions of the world.	UCLG (2012)	6	48
Smart city benchmarking in China	A benchmarking developed in a Chinese project and used for evaluating smartness of 28 Chinese cities.	Zhang (2012)	5	43
Triple-helix network model for smart cities performance	A model analyzing interrelations between the components of smart cities, including the human and social relations.	Lombardi et al. (2011)	5	45
Smart City PROFILES	A set of smart city indicators, with a focus on climate change and energy efficiency for five urban areas, developed in cooperation with 12 cities.	Smart City PROFILES (2013)	5	21
City Protocol	An international collaborative innovation framework that fosters city-centric solutions which benefit citizens. A set of indicators have been developed, by extending the ISO 37120.	City Protocol Society (2015)	9	190
CITYkeys	An EU-project (under the H2020 program) with the aim to provide a validated, holistic performance measurement framework for monitoring and comparing the implementation of smart city solutions.	Bosch et al. (2016); Huovila et al. (2016)	20	73

(Tanguay et al., 2010). However, weighting is not considered in our study because weights were not part of most of the frameworks analyzed. Weights are also typically target group specific. For example, city managers, urban planners, experts, policy makers, companies and citizens will certainly have different priorities. Since our research doesn't analyze user group specific differences, it seems appropriate also to leave out weighting from our analysis. Also, we are only interested about measuring the coverage to specific aspects or issues, not assessing how each indicator contributes to the final result relative to the purpose of the specific performance measurement system. Exploring the indicators of an assessment system in amount provides us information about what is considered as important by that framework. If an issue is measured with several indicators, it suggests that this issue is considered as quite relevant. Our analysis also does not include normalization of indicators to equalize the importance of different frameworks (the number of indicators in each framework varies). This seems appropriate since the objective is not to compare individual frameworks but to compare the use of the smart and sustainable indicators. Also, since the differences between smart and sustainability indicators are analyzed with proportions (as percentages), the difference in total number of smart and sustainability indicators doesn't affect the results of the analysis.

To study the differences of the two types of performance measurement systems (smart city versus urban sustainability), the original categorizations of indicators presented by the frameworks were abandoned and the indicators were regrouped under new categories. Two types of categories were formed: *impact categories* and *sector categories*.

For impact categories we chose the traditional three dimensions of sustainability: *economic*, *social* and *environmental*. Since the first introduction of these three dimensions of sustainability (WCED, 1987) the idea of sustainability standing on these three pillars has been further introduced in a great number of urban sustainability studies (e.g. Giddings, Hopwood, & O'Brien, 2002), and hence this choice of categorization seemed the most appropriate. By dividing the indicators under these three categories we received an answer to the question “which

Table 2
The eight sustainable city assessment frameworks considered in the study.

Name of the framework	Description	Source	Number of	
			Categories	Indicators
ISO 37120 Sustainable development of communities — Indicators for city services and quality of life	A standard with a set of indicators assessing the performance of cities' service delivery and quality of life in order to provide a holistic and integrated approach to sustainable development and resilience.	ISO (2014)	17	100
Reference framework for European sustainable cities (RFSC)	A free of charge web tool for European local authorities designed to help cities and urban territories promote and improve their integrated urban development actions.	Ministère de l'Égalité des territoires et du Logement (2014)	4	24
BREEAM Communities	An assessment method providing “a way to improve, measure and certify the social, environmental and economic sustainability of large scale development plans.”	BREEAM (2011)	9	62
LEED for Neighborhood Development (LEED ND)	A green certification concept applied to the neighborhood context, containing a set of measurable standards that identify whether the development is environmentally superior.	LEED	5	53
CASBEE for Urban Development (CASBEE-UD)	An environmental performance assessment tool for urban scale focusing on the phenomena which might be consequences of conglomeration of buildings.	CASBEE (2007)	6	76
STATUS - Sustainability Tools And Targets for the Urban Thematic Strategy project	A joint initiative by researchers and local practitioners to develop locally relevant tools enabling establishment of targets towards urban sustainability.	Evans and Fenton (2006)	8	46
SustainLane	Sustainability ranking of the 50 largest US cities. Considers each major city's management policies, strengths and challenges and the potential of clean technologies.	Post Carbon Cities (2007); Sustain Lane Criteria	16	46
UN Habitat indicators	20 key indicators, 8 check-lists and 16 extensive indicators which measure performances and trends in reaching the Habitat Agenda and the Millennium Development Goals adopted by the United Nations.	United Nations Human Settlements Programme (2004)	5	42

type of sustainability is the indicator measuring/where can the impact be seen?" While this categorization is traditionally used only for sustainability indicators, the same impacts are relevant also for smart cities to measure how well their ultimate objectives are reached. While it is often useful to measure with a smart city output indicator the performance of a certain technology, it is also a valid question to evaluate whether that technology is at the end economically viable, societally desirable or environmentally feasible. Even though not always simple, it is possible to estimate the potential main impact categories of the output indicators as done in our study. For example, an indicator measuring the number of smart energy meters installed can be expected to be mainly used to achieve environmental impacts while the indicator "number of open datasets" could be estimated to have mostly social impacts. Finally, "the number of new start-ups" is clearly an economic indicator.

To reach a better understanding of the focus of the indicators, we further divided the indicators under a number of sectors. By this means we received an answer to the question "which sector/sectors is the indicator related to?" As the result of an in-depth literature review Neirotti et al. (2014) presented 12 domains which are highlighted in a number of urban development studies. We followed the principle of these domains when selecting our sector categories but adapted them to better cover all essential functions of cities. The 10 sector categories chosen are *Natural environment*; *Built environment*; *Water and waste management*; *Transport*; *Energy*; *Economy*; *Education, culture, science and innovation*; *Well-being, health and safety*; *Governance and citizen engagement* and *ICT*.

We carried out the analysis by dividing each of the 958 indicators under the three impact categories and 10 sector categories. Fig. 1 illustrates the procedure step by step. Because many of the indicators are related to more than one sector, and the impact might also be seen in several categories, each indicator was allocated four points in total of which two were distributed under one or two chosen sector categories and the other two under one or two chosen impact categories (step 1 in Fig. 1). As an example, the indicator "Penetration of ICT use in education" is clearly related to two sectors: *ICT* and *Education, culture, science and innovation,* and therefore one point was given to each. As another example "Poverty rate" is related to two impact categories: *social sustainability* (wellbeing of citizens) but simultaneously to *economic sustainability* (affluence/economic wellbeing of the city) and hence both categories were given one point. After distributing the four points under appropriate categories for each indicator, a matrix was developed (with sector categories as the vertical row and impact categories as the horizontal row), by calculating for each entry a scalar product between the vectors consisting of points of corresponding sectors and impacts (step 2). In step 3, the points distributed under each impact and sector category in the matrix, were summed.

Finally, we used a *t*-test to determine whether the differences between the two types of assessment frameworks are statistically significant. We carried out the analysis for each impact category (three categories) and sector category (ten categories) and formed two sample groups: sample group 1 comprising all the eight smart city frameworks and sample group 2 comprising all the eight urban sustainability frameworks. The test carried out was a two-tailed *t*-test for independent samples, assuming unequal variances. The variables of the study were the points (as percentages) distributed under each impact category and sector category. Using percentages instead of actual points was necessary due to the varying number of indicators of the studied frameworks.

3. Results

3.1. Division of indicators under sector and impact categories

Tables 3 and 4 summarize the results of the indicator analysis of the smart city and urban sustainability frameworks. The tables show (as percentages) the division of indicators (or the points allocated for each indicator during this study) under the 10 sector categories and three impact categories. The following observations can be made: First, regarding the smart city frameworks, the dimension of social sustainability is significantly overrepresented, covering more than half of the indicators. Economic sustainability is measured by a bit less than one third of the indicators, whereas environmental sustainability is slightly underrepresented, with only 20% of the indicators belonging under this dimension. This suggests that the smart city targets are highly related to social aspects whereas environmental issues are considered less important. Second, the division of the smart city indicators across the 10 sector categories supports the observation above, as *Economy*, *Education, culture, science and innovation* and *Well-being, health and safety* score highest (covering 19%, 16% and 15% of the indicators respectively). Also, *Governance and citizen engagement* and *ICT* cover a significant share of indicators (11%) whereas a clear minority of indicators belong under the sectors of *Natural environment* (7%), *Water and waste management* (7%), *Transport* and *Energy* (6%) and *Built environment* (4%).

The main observation from the urban sustainability framework study is that the indicators are evenly covering the environmental and social dimensions (43% and 47%), whereas indicators measuring economic sustainability are representing a clear minority (10%). Also, regarding the division of urban sustainability indicators under the 10 sectors, the majority of the indicators are covering the sectors of *Natural environment* (16%), *Built environment* (13%), *Water and waste management* (14%), *Transport* (12%) and *Well-being, health and safety* (16%). Indicators covering the sectors of *Energy* (6%), *Economy* (9%), *Education, culture, science and innovation* (5%) and *Governance and citizen engagement* (8%) are representing a minority, but only the *ICT* sector has very low share of indicators (2%).

3.2. Comparison of the two types of assessment frameworks

Fig. 2 presents an illustration of how the indicators of both performance measurement system types cover the three dimensions of sustainability. As already explained in the earlier section, smart city frameworks have a clear focus on social aspects, while particularly environmental aspects seem less significant. Also the urban sustainability frameworks focus strongly on social aspects, and almost as much on environmental aspects, whereas the economic dimension is almost ignored.

Interestingly, both performance measurement system types highlight the social dimension of sustainability and therefore we took a closer look on the focus on different sectors within this dimension.

As can be observed in Fig. 3, the main differences between the two types of frameworks regarding the social sustainability is that while smart cities focus much more on *Education, culture, science and innovation* and *ICT*, the urban sustainability frameworks focus on more environment related sectors, such as *Natural* and *Built environment*, *Water and waste management* and *Transport*. However, *Well-being, health and safety* is the sector under which about one third of the indicators fall in both types of assessment systems suggesting that rather similar aspects are covered regarding the social sustainability dimension.

How the ten sectors are covered in total by the two types of frameworks is illustrated in Fig. 4 (now all the dimensions are included in the analysis). The following observations can be made: *Education, culture, science and innovation* and *Economy* which are two out of the three major sector categories for the smart city frameworks, are far less covered by the urban sustainability frameworks. Also ICT is much more important for smart city frameworks. On the other hand, more environment related sectors such as *Natural* and *built environment*, *Water and waste management* and *Transport* which are widely covered by the urban sustainability frameworks are almost ignored by the smart city frameworks.

Finally, in order to determine whether the differences between the two types of frameworks are statistically significant, we carried out a *t*-test. As shown in Table 5, the difference in the distribution of indicators under the three dimensions of sustainability is significant for

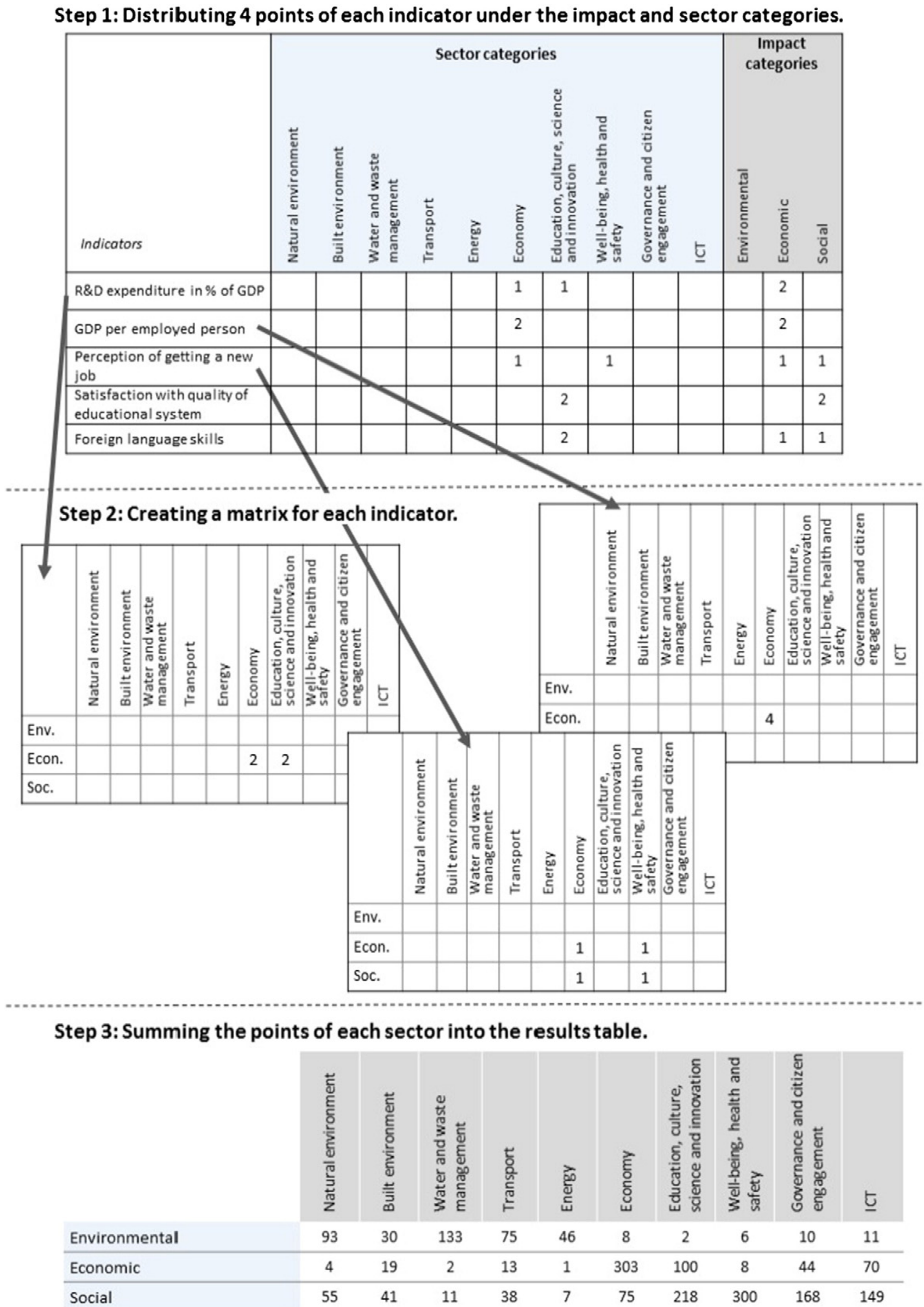

Fig. 1. An illustration of the process of distributing indicators under the three impact and 10 sector categories.

environmental and economic sustainability, but insignificant for social sustainability. This is in line with the results presented in Fig. 2.

Regarding the sector categories, the difference was significant for five sectors (*Natural environment*, *Built environment*, *Water and waste management*, *Economy* and *Education, culture, science and innovation*) but insignificant for the other five. These results are in line with Fig. 4 with the exception of ICT, which seems to be much more addressed in the smart city frameworks than in urban sustainability frameworks. However, the insignificant difference indicated by the statistical analysis can be explained by the observation that even if most of the smart city

Table 3
Division of the indicators of smart city frameworks under the ten sectors and three impact categories.

		Impact categories			
		Environmental sustainability	Economic sustainability	Social sustainability	*In total*
Sectors	Natural environment	5%	0%	3%	*7%*
	Built environment	1%	1%	2%	*4%*
	Water and waste management	7%	0%	1%	*7%*
	Transport	4%	1%	2%	*6%*
	Energy	2%	0%	0%	*3%*
	Economy	0%	15%	4%	*19%*
	Education, culture, science and innovation	0%	5%	11%	*16%*
	Well-being, health and safety	0%	0%	15%	*15%*
	Governance and citizen engagement	0%	2%	8%	*11%*
	ICT	1%	3%	7%	*11%*
	In total	*20%*	*28%*	*52%*	*100%*

frameworks have several indicators measuring ICT, a few of the frameworks however have none or only few (please see Appendix 1).

4. Discussion

Cities today show a growing concern about sustainability issues and they are increasingly trying to find means to preserve natural and economic resources. Earlier the discussion has considered sustainability of cities but in recent years the interest in how sustainability targets can be achieved with help of "smartness" has led to an increasing popularity of the smart city concept. Several performance measurement systems have been developed in order to enable cities to assess their progress towards smart city targets.

The aim of our study was to explore to what extent the smart city concept addresses the same issues as the sustainable city concept. To examine the differences we studied the indicator assessment frameworks used to evaluate both sustainable and smart urban performance. Even though the definition of the smart city concept has been the subject of a vast number of studies, our approach, in which we compare smart cities to sustainable cities is rather unique. Only the study by Monfaredzadeh and Berardi (2015) used a similar method, comparing the indicators used in smart, sustainable and competitive city rating systems. However, the approach of our study differs from this one regarding the categories which were examined. While Monfaredzadeh and Berardi (2015) focused on the most common smart city clusters, we took a close look on the three traditional dimensions of sustainability as well as ten (smart) sector categories to develop a profound understanding of how the two types of frameworks differ from each other (examining both, which are the dimensions where the impact can be seen and which sectors are the indicators related to).

Weighting factors were not part of most of the frameworks analyzed and, even when available, they often differ between target groups considered. Therefore, the potential effect of weights on the significance of different indicators was consistently neglected in order to ensure the uniformity of the research method. In the few cases when such existed, the results might be slightly distorted and therefore slight caution is recommended when drawing conclusions based on the magnitude of the differences observed. The differences between sustainable and smart city indicators are, however, so significant that the main conclusions remain valid.

Much stronger emphasis on ICT and "smartness" in the smart city assessment frameworks compared to the urban sustainability frameworks was an expected observation of our study. Another, more surprising finding is that as urban sustainability assessments mainly focus on the dimension of environmental sustainability, the smart city assessments lack environmental indicators while focusing much more on social and economic aspects.

When analyzing the application domains of smart city indicators, our results corroborate the recent findings of Monfaredzadeh and Berardi (2015) according to whom the smart city systems emphasize human and virtual environment instead of the physical one. In our study areas such as *Natural environment*, *Built environment*, *Water and waste management* and *Energy* are indeed more comprehensively addressed by urban sustainability assessment systems while economic issues are better covered by smart city frameworks. However, when comparing the existing indicators to the domains of practical smart city applications, a surprising incoherence can be observed. The sectors of *Transport* and *Energy* have really small numbers of smart city indicators while massive resources (Vanolo, 2014) have been spent during the past years in Europe on smart city research projects, and more recently on smart city lighthouse demonstration projects, that mainly focus on the sectors of energy, transport and ICT (European Commission, 2012). Also according to Neirotti et al. (2014) transportation and mobility as well as natural resources and energy are the application domains with most existing smart city initiatives.

The strong focus on social indicators in the smart city frameworks could be seen as improvement to the criticism according to which social sustainability aspects have continuously received only limited

Table 4
Division of the indicators of urban sustainability frameworks under the ten sectors and three impact categories.

		Impact categories			
		Environmental sustainability	Economic sustainability	Social sustainability	*In total*
Sectors	Natural environment	11%	0%	5%	*16%*
	Built environment	5%	1%	7%	*13%*
	Water and waste management	10%	0%	3%	*14%*
	Transport	7%	0%	4%	*12%*
	Energy	5%	0%	1%	*6%*
	Economy	1%	5%	3%	*9%*
	Education, culture, science and innovation	0%	1%	3%	*5%*
	Well-being, health and safety	0%	0%	15%	*16%*
	Governance and citizen engagement	2%	1%	5%	*8%*
	ICT	0%	0%	1%	*2%*
	In total	*43%*	*10%*	*47%*	*100%*

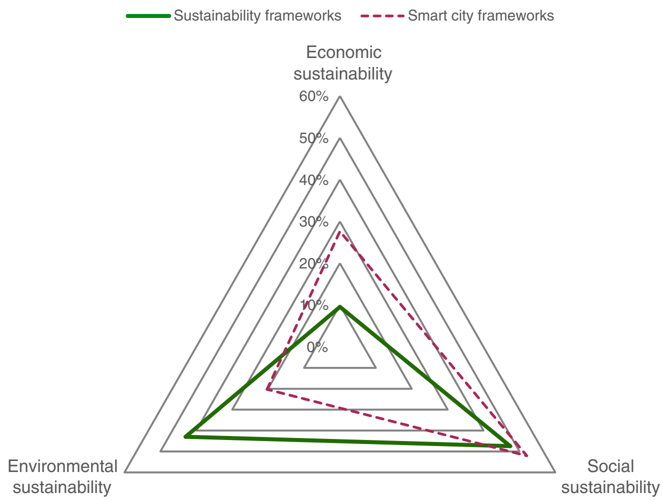

Fig. 2. Division of the number of indicators for both smart city urban sustainability frameworks under the three dimensions of sustainability.

attention (for example Vallance, Perkins, & Dixon, 2011; Murphy, 2012) and possibilities for citizens to participate for example in urban planning have been minor (e.g. Kathlene & Martin, 1991; Ford, 2010). Similarly, the importance of economic sustainability suggests that finally it has been understood that economic advantages do not contradict with other sustainability targets: when reaching for environmental sustainability of a city, economic activities do not need to be compromised but instead they can co-benefit from the environmental sustainability targets (Geary, 2004; Nixon, 2009; McKinsey and Company, 2011).

However, the small number of environmental indicators in the smart city frameworks is a remarkable deficiency because reducing energy consumption and CO_2 emissions is one of the major goals of smart cities (European Commission, 2012; United Nations, 2015b). One possible explanation is that sectors related to environmental issues, such as energy and transport, are rather straightforward to assess whereas some of the social and economic aspects, such a social inclusion and governance, are much more complex issues therefore needing a larger number of indicators. This however does not explain the clear lack of some basic environmental indicators from many of the smart city frameworks while they do exist in the urban sustainability assessments.

5. Conclusions

The purpose of the smart city assessment frameworks is to give guidance for decision-making, enable target setting for cities as well as allow assessing whether the development is proceeding towards the wanted direction. The large number and dispersion of smart city definitions however poses challenges to the target setting of cities, which has similarly been presented as a challenge for the sustainability concept (Tanguay et al., 2010).

The comparison of the two types of performance measurement systems suggests that the initial target of smart cities, defined as attaining sustainability of a city with help of modern technologies, is not sufficiently addressed in some of the smart city frameworks. While environmental sustainability is an essential target of smart cities (European Commission, 2012; United Nations, 2015b) environmental indicators are clearly underrepresented in the smart city frameworks analyzed in our study. Also, considering the ambitious European (European Commission, 2014) and global (United Nations, 2016) energy and GHG emission mitigation targets, decreasing energy use should be an important goal for smart cities. Surprisingly, according to our study it seems that the use of energy related indicators is rather limited in the smart city frameworks, when compared to urban sustainability assessment. Instead, smart city frameworks have a large variety of indicators

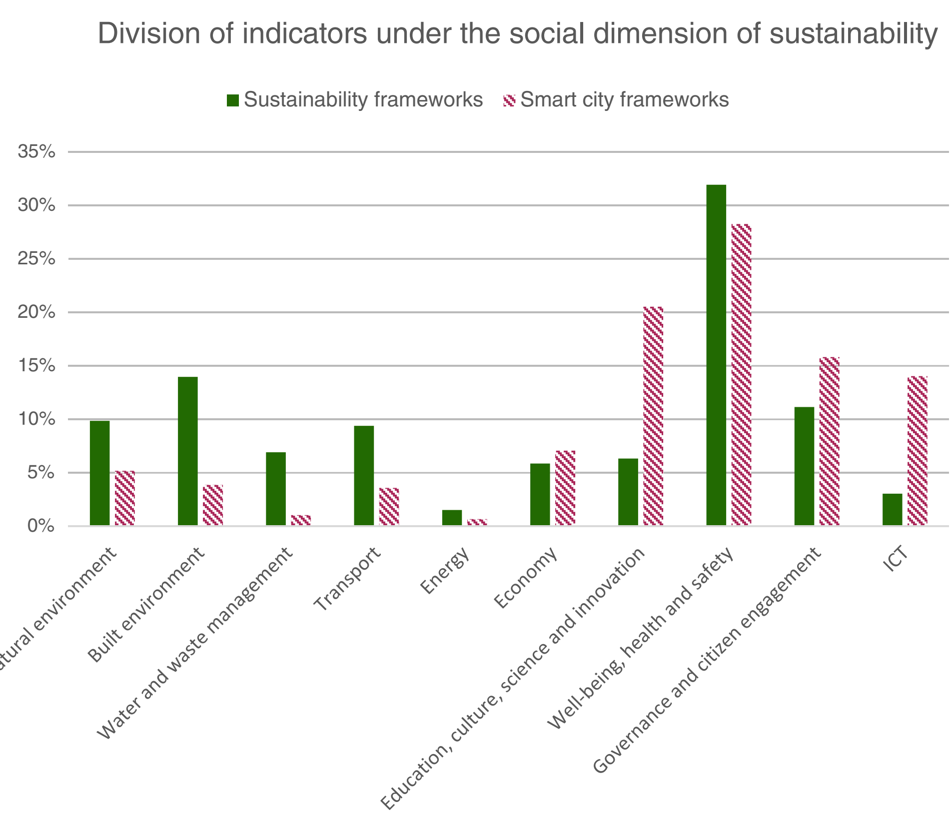

Fig. 3. Division of the sustainable and smart indicators under different sectors within the social dimension.

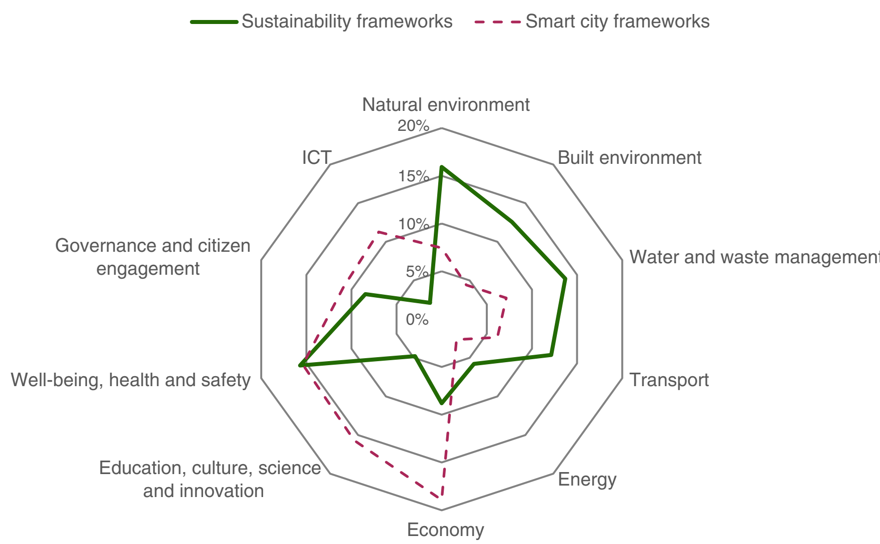

Fig. 4. Division of the indicators of both smart city urban sustainability frameworks under the ten sector categories.

considering economic and social aspects of a city. This suggests that environmental and energy related aspects may not be considered to a sufficient extent in the smart city frameworks indicating some future development needs for smart city performance measurement systems or a need for redefining the smart city concept.

In our opinion, the role of technologies in smart cities should be in enabling sustainable development of cities as suggested by Bifulco et al. (2016), not in the new technology as an end in itself (Marsal-Llacuna & Segal, 2016). Ultimately, a city that is not sustainable is not really "smart". Sometimes the fashionable term "smart city" is also used for branding (Vanolo, 2015) or marketing (Shelton, Zook, & Wiig, 2015; Söderström, Paasche, & Klauser, 2014) purposes with lack of integrated approach covering sustainability concerns. Our position is that sustainability assessment should be part of smart city development and therefore we find it important to integrate sustainability and smart city frameworks so that both views are accounted for in performance measurement systems. We therefore recommend the use of a more accurate term "smart sustainable cities" (instead of "smart cities"), as suggested also by Kramers, Höjer, Lövehagen, and Wangel (2014). Its use will hopefully help in ensuring that sustainability is not neglected in smart city development. This terminology has been recently adopted also by some European (CEN-CENELEC-ETSI, 2015) and international (ITU, 2016) standardization bodies. We also strongly recommend that the assessment of smart city performance should not only use output indicators that measure the efficiency of deployment of smart solutions but always also impact indicators that measure the contribution towards the ultimate goals such as environmental, economic or social sustainability.

Table 5
The results of the *t*-test for analyzing the significance of differences between the two types of frameworks.

	Smart city frameworks		Urban sustainability frameworks		p	t
	M (%)	SD (%)	M (%)	SD (%)		
Impact categories						
Environmental sustainability	20	16.8	43.4	18.5	0.020*	2.619
Economic sustainability	30.1	13.9	10.6	8.3	0.006*	3.419
Social sustainability	49.6d	11.2	46.1	15.4	0.612	−0.520
Sector categories						
Natural environment	6.2	4.3	16.1	8.4	0.013*	2.948
Built environment	3.8	4.6	12.7	9.5	0.038*	2.392
Water and waste management	5.2	4.8	12.0	6.4	0.030*	2.438
Transport	5.9	4.6	12.0	7.5	0.073	1.963
Energy	3.0	2.4	5.4	2.8	0.084	1.859
Economy	19.6	9.3	9.9	7.1	0.036*	2.335
Education, culture, science and innovation	16.6	7.1	5.2	4.3	0.002*	3.878
Well-being, health and safety	13.2	5.9	14.6	9.2	0.720	0.367
Governance and citizen engagement	12.1	3.6	10.2	7.7	0.553	−0.613
ICT	14.4	15.9	1.9	2.1	0.064	2.194

* Statistical significance at the $p < 0.05$ level.

Also the importance of environmental impacts caused by the use of smart technologies has been recognized by the ITU (International Telecommunication Union, a United Nations agency responsible for ICT). The standard recommendation ITU-T L.1440 "Methodology for environmental impact assessment of information and communication technologies at city level" provides a method for calculating the life cycle impacts of ICT. According to the standard, it should be calculated whether producing ICT/smart equipment has higher environmental impact than the impacts that the equipment can mitigate during its lifetime (ITU, 2015) As an example, in the case of smart meters, the net impact is the difference between the environmental impacts caused by the production of the meters and the impacts of the energy which can be saved because of them. This kind of impact assessment, typically missing from existing frameworks, should, in our opinion, be included in future smart city performance assessment systems.

Our study focused on analyzing the differences between sustainable and smart cities based on the amount of indicators available in different frameworks. Future research could carry out empirical analyses on which indicators cities actually use to measure smart city performance and how well those indicators serve their use purpose. Also, it would be interesting to compare how well smart city and sustainability performance correlate; if a city gets a certain rating when assessed with a smart city performance measurement framework, will it perform similarly also when analyzed with a sustainability framework?

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Appendix 1. Division of smart city and urban sustainability frameworks under 10 sector categories and three impact categories.

	Smart city frameworks									Urban sustainability frameworks								
	1. European Smart City ranking	2. Smart cities wheel	3. Bilbao Smart cities study	4. Smart cities benchmarking in china	5. Triple helix model	6. Smart City Profiles	7. Cityprotocol	8. Citykeys	*In total*	1. ISO 37120	2. RFSC	3. BREEAM	4. LEED	5. CASBEE	6. STATUS (ICLEI)	7. Sustain Lane	8. UN HABITAT	*In total*
Number of indicators	64	26	48	43	45	21	190	73	*510*	100	24	62	53	75	46	46	42	*448*
Distributing the points among sectors[a]																		
Sectors																		
Natural environment	9	3	0	2	4	3	34	21	*76*	19	8	15	19	39	24	18	1	*143*
Built environment	0	2	0	0	0	5	27	11	*45*	4	2	36	26	19	9	7	10	*113*
Water and waste management	2	2	0	0	4	4	47	14	*73*	41	0	10	12	24	16	9	11	*123*
Transport	4	4	0	3	2	6	33	11	*63*	17	2	28	14	12	10	22	4	*109*
Energy	2	3	0	1	2	3	11	5	*27*	12	2	7	10	11	7	2	1	*52*
Economy	26	8	26	12	35	4	59	23	*193*	24	11	11	6	3	1	11	12	*79*
Education, culture, science and innovation	36	8	17	10	24	5	46	14	*160*	16	7	3	6	3	2	2	4	*43*
Well-being, health and safety	31	7	10	11	6	4	75	13	*157*	50	7	8	10	30	10	2	24	*141*
Governance and citizen engagement	18	5	11	10	8	7	27	25	*111*	11	7	5	3	3	11	19	17	*76*
ICT	0	10	32	37	5	1	21	9	*115*	6	2	1	0	8	2	0	0	*19*
Impact categories																		
Environmental	11	13	0	6	11	22	99	45	*207*	64	14	56	60	60	66	54	12	*386*
Economic	36	10	54	27	40	7	69	39	*282*	25	13	17	11	4	0	6	10	*86*
Social	81	29	42	53	39	13	212	62	*531*	111	21	51	35	88	26	32	62	*426*

[a] Each indicator has two points which can be distributed among one or two sectors, and two points which can be distributed among one or two dimensions.

References

Albino, V., Berardi, U., & Dangelico, R. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology*, *22*(1), 3–21. http://dx.doi.org/10.1080/10630732.2014.942092.

Angelidou, M. (2014). Smart city policies: A spatial approach. *Cities*, *41*(S1), S3–S11. http://dx.doi.org/10.1016/j.cities.2014.06.007.

Angelidou, M. (2015). Smart cities: A conjuncture of four forces. *Cities*, *47*, 95–106. http://dx.doi.org/10.1016/j.cities.2015.05.004.

Belanche, D., Casaló, L., & Orús, C. (2016). City attachment and use of urban services: Benefits for smart cities. *Cities*, *50*, 75–81. http://dx.doi.org/10.1016/j.cities.2015.08.016.

Berardi, U. (2013). Sustainability assessment of urban communities through rating systems. *Environment, Development and Sustainability*, *15*, 1573–1591. http://dx.doi.org/10.1007/s10668-013-9462-0.

Bifulco, F., Tregua, M., Amitrano, C., & D'Auria, A. (2016). ICT and sustainability in smart cities management. *International Journal of Public Sector Management*, *29*(2), 132–147. http://dx.doi.org/10.1108/IJPSM-07-2015-0132.

Bosch, P., Jongeneel, S., Rovers, V., Neumann, H. -M., Airaksinen, M., & Huovila, A. (2016). Deliverable 1.4 smart city KPIs and related methodology – Final. CITYkeys project. http://nws.eurocities.eu/MediaShell/media/D1.4-CITYkeys_D14_Smart_City_KPIs_Final_20160201.pdf (accessed 15.5.2016)

Bourdic, L., Salat, S., & Nowacki, C. (2012). Assessing cities: A new system of cross-scale spatial indicators. *Building Research and Information*, *40*(5), 592–605. http://dx.doi.org/10.1080/09613218.2012.703488.

BREEAM (2011). BREEAM for communities: Stage 2. http://www.breeam.org/filelibrary/BREEAM%20Communities/BREEAM_Communities_Stage_2_Version_1_280211v1.pdf (accessed 20.2.2016)

CAI-Asia Program (d). Sustainable urban transport in Asia. Making the vision a reality. http://pdf.wri.org/sustainable_urban_transport_asia.pdf (accessed 20.2.2016)

Calzada, I., & Cobo, C. (2015). Unplugging: Deconstructing the smart city. *Journal of Urban Technology*, *22*(1), 23–43. http://dx.doi.org/10.1080/10630732.2014.971535.

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. *Journal of Urban Technology*, *18*(2), 65–72. http://dx.doi.org/10.1080/10630732.2011.601117.

CASBEE (2007). CASBEE for urban development. *Technical manual 2007 edition*. Institute for Building Environment and Energy Conservation (IBEC).

Castells, M. (2000). Urban sustainability in information age. *City*, *4*(1), 118–122. http://dx.doi.org/10.1080/713656995.

CEN-CENELEC-ETSI (2015). SSCC-CG final report. Smart and Sustainable Cities and Communities Coordination Group. ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/Fields/SmartLiving/City/SSCC-CG_Final_Report-recommendations_Jan_2015.pdf (accessed 18.4.2016)

Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J. R., Mellouli, S., Nahon, K., ... Scholl, H. J. (2012). *Understanding smart cities: An integrative framework* (pp. 2289–2297)45th Hawaii International Conference on Systems Science (HICSS-45 2012), Proceedings, 4–7 January 2012, Grand Wailea, Maui, HI, USA.

City Protocol Society (2015). City anatomy indicators. City Protocol Agreement CPA-I_001-v2 of the City Protocol Society. http://www.cptf.cityprotocol.org/CPAPR/CPA-PR_002_Anatomy_Indicators.pdf (accessed 14.4.2016)

CIVITAS (d). http://www.civitas.eu (accessed 20.2.2016)

Cohen, B. (d). http://www.boydcohen.com/smartcities.html (accessed 20.2.2016)

Cole, R. (2012). Transitioning from green to regenerative design. *Building Research and Information*, *40*(1), 39–53. http://dx.doi.org/10.1080/09613218.2011.610608.

CONCERTO (d). http://concerto.eu/concerto/ (accessed 20.2.2016)

Correia, L. M., & Wünstel, K. (2011). Smart cities applications and requirements. White paper. Net!Works European Technology Platform. http://www.networks-etp.eu/fileadmin/user_upload/Publications/Position_White_Papers/White_Paper_Smart_Cities_Applications.pdf (accessed 20.2.2016)

Covenant of Mayors ( ). http://www.covenantofmayors.eu/index_en.html (accessed 20.2.2015)

Dameri, R., & Cocchia, A. (2013). *Smart city and digital city: Twenty years of terminology evolution* (pp. 1–8)X Conference of the Italian Chapter of AIS, ITAIS 2013, Università Commerciale Luigi Bocconi, Milan (Italy).

Debnath, A. K., Chin, H. C., Haque, M., & Yuen, B. (2014). A methodological framework for benchmarking smart transport cities. *Cities*, *37*, 47–56. http://dx.doi.org/10.1016/j.cities.2013.11.004.

Directorate of Urban Land Transport (2011). Bangalore mobility indicators 2010–2011. http://www.urbantransport.kar.gov.in/Bangalore%20Mobility%20Indicators_(22-12-2011).pdf (accessed 10.2.2016)

Economist Intelligence Unit (2005). *The economist intelligence unit's quality of life index. The world in 2005*. , 1–4http://www.economist.com/media/pdf/QUALITY_OF_LIFE.pdf (accessed 20.2.2016)

EERA Joint Programme on Smart Cities (2013). http://www.eera-sc.eu/sites/eera-sc.eu/files/attachments/smartcitiesbrosch_lowres_single_pages.pdf (accessed 21.6.2016)

European Commission (2012). Communication from the commission. Smart cities and communities – European innovation partnership. Brussels. http://ec.europa.eu/energy/technology/initiatives/doc/2012_4701_smart_cities_en.pdf (accessed 10.2.2016)

European Commission (2014). Climate action. http://ec.europa.eu/clima/policies/2030/index_en.htm (accessed 20.2.2016)

European Union (2011). Cities of tomorrow. Challenges, visions, ways forward. Brussels. http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/citiesoftomorrow/citiesoftomorrow_final.pdf (accessed 20.2.2016)

Evans, B., & Fenton, P. (2006). The STATUS Project - Researchers and practitioners identify common indicators for urban sustainability target-setting in Europe. RELAy – Research for Local Action towards Sustainable Human Settlements (2005/2006). http://relay.iclei-europe.org/fileadmin/user_upload/relay/Case_studies/evans_fenton_STATUS_summary.pdf (accessed 20.2.2016)

Ford, K. (2010). *The trouble with city planning. What New Orleans can teach us*. Yale University Press (ISBN: 9780300127355).

Garau, C., Masala, F., & Pinna, F. (2015). Benchmarking smart urban mobility: A study of Italian cities. *Computational science and its applications - ICCSA 2015* (pp. 612–623). Switzerland: Springer International Publishing (2015).

Garau, C., Masala, F., & Pinna, F. (2016). Cagliari and smart urban mobility: Analysis and comparison. *Cities*, *56*, 35–46. http://dx.doi.org/10.1016/j.cities.2016.02.012.

Geary, C. (2004). *Sustainable connections: Linking sustainability and economic development strategies*. National League of Cities. Centre for Research & Innovationhttp://www.nlc.org/documents/Find%20City%20Solutions/Research%20Innovation/Sustainability/sustainable-connections-linking-sustainability-and-economic-development-strategies-cpb-jun11.pdf (accessed 10.2.2016)

Gibson (1982). Working with the performance approach in building. *International Council for Research and Innovation in Building and Construction (CIB), CIB report, publication no. 64. Rotterdam, Netherlands*.

Giddings, B., Hopwood, B., & O'Brien, G. (2002). Environment, economy and society: Fitting them together into sustainable development. *Sustainable Development*, *10*, 187–196. http://dx.doi.org/10.1002/sd.199.

Giffinger, R., Fertner, C., Kramar, Kalasek, R., Pichler-Milanović, N., & Meijers, E. (2007). *Ranking of European medium-sized cities*. Vienna UT, October: Centre of Regional Sciencehttp://www.smart-cities.eu/download/smart_cities_final_report.pdf (accessed 20.2.2016)

Gonzales, J. A. A., & Rossi, A. (2011). New trends for smart cities, open innovation mechanisms in smart cities. European commission with the ICT policy support programme. http://ec.europa.eu/information_society/apps/projects/logos//6/270896/080/deliverables/001_D2221NewtrendsforSmartCities.pdf (accessed 20.2.2016)

Green Digital Charter (d). http://www.greendigitalcharter.eu (accessed 20.2.2016)

Haapio, A. (2012). Towards sustainable urban communities. *Environmental Impact Assessment Review*, *32*, 165–169. http://dx.doi.org/10.1016/j.eiar.2011.08.002.

Harrison, C., & Donnely, I. (2011). A theory of smart cities. *Proc of the 55th annual meeting ISSS*, *55*(1), 1–15.

Hedman, Å., Sepponen, M., & Virtanen, M. (2014). Energy efficiency rating of districts, case Finland. *Energy Policy*, *65*, 408–418. http://dx.doi.org/10.1016/j.enpol.2013.10.022.

Hiremath, R. B., Balachandra, P., Kumar, B., Bansode, S. S., & Murali, J. (2013). Indicator-based urban sustainability – A review. *Energy for Sustainable Development*, *17*, 555–563. http://dx.doi.org/10.1016/j.esd.2013.08.004.

Hollands, R. G. (2008). Will the real smart city please stand up? *City*, *12*(3), 303–320. http://dx.doi.org/10.1080/13604810802479126.

Huang, S. -L., Yeh, C. -T., Budd, W. W., & Chen, L. -L. (2009). A Sensitivity Model (SM) approach to analyze urban development in Taiwan based on sustainability indicators. *Environmental Impact Assessment Review*, *29*, 116–125. http://dx.doi.org/10.1016/j.eiar.2008.03.003.

Hung-Nien, H., Chiu-Yao, C., Chung-Chih, C., & Yuan-Yu, C. (2011). *The evaluating indices and promoting strategies for intelligent city in Taiwan* (pp. 6704–6709)Proceedings of the International Conference on Multimedia Technology (ICMT), 26–28 July 2011, Hangzhou.

Huovila, A., Penttinen, T., Airaksinen, M., Pinto-Seppä, I., Piira, K., & Penttinen, T. (2016). *Smart city performance measurement system*Accepted for the Proceedings of the 41th IAHS World congress "Sustainability and innovation for the future", 13–16 September 2016, Albufeira, Portugal.

IEEE (the Institute of Electrical and Electronics Engineers) (2014s). IEEE smart cities. http://smartcities.ieee.org/about.html (accessed 20.2.2016)

International Living (2014). http://internationalliving.com/world-rankings/ (accessed 20.2.2016)

ISO (International Standardization Organization) (2010). *ISO 21929:2010 Building construction – Sustainability in building construction – Sustainability indicators. Part 1 - Framework for the development of indicators for buildings and core indicators*.

ISO (International Standardization Organization) (2014). *ISO 37120:2014 Sustainable development of communities — Indicators for city services and quality of life*.

ITU (2016). ITU-T focus group on smart sustainable cities. http://www.itu.int/en/ITU-T/focusgroups/ssc/Pages/default.aspx (accessed 18.4.2016)

ITU (International Telecommunication Union) (2015). *ITU-T L.1440 Methodology for environmental impact assessment of information and communication technologies at city level. An approved and pre-published standard recommendation of the International Telecommunication Union*.

Jucevicius, R., Patašienė, I., & Patašius, M. (2014). Digital dimension of smart city: Critical analysis. *Procedia - Social and Behavioral Sciences*, *156*, 146–150. http://dx.doi.org/10.1016/j.sbspro.2014.11.137.

Kathlene, L., & Martin, J. A. (1991). Enhancing citizen participation: Panel designs, perspectives, and policy formation. *Journal of Policy Analysis and Management*, *10*(1), 46–63. http://dx.doi.org/10.2307/3325512.

Kramers, A., Höjer, M., Lövehagen, N., & Wangel, J. (2014). Smart sustainable cities – Exploring ICT solutions for reduced energy use in cities. *Environmental Modelling & Software*, *56*, 52–62. http://dx.doi.org/10.1016/j.envsoft.2013.12.019.

Lazaroiu, G., & Roscia, M. (2012). Definition methodology for the smart cities model. *Energy*, *47*(1), 326–332.

Lee, J. -H., & Hancock, M. G. (2012). *Towards a framework for smart cities: A comparison of Seoul, San Francisco and Amsterdam*. Stanford Program on Regions of Innovation and Entrepreneurshiphttp://iis-db.stanford.edu/evnts/7239/Jung_Hoon_Lee_final.pdf (accessed 20.2.2016)

Lee, J. H., Hancock, M. G., & Hu, M. -C. (2014). Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. *Technological Forecasting and Social Change*, *89*, 80–99. http://dx.doi.org/10.1016/j.techfore.2013.08.033.

LEED (d). A citizen's guide to LEED for neighborhood development: How to tell if development is smart and green. https://www.nrdc.org/cities/smartgrowth/files/citizens_guide_LEED-ND.pdf (accessed 23.2.2016)
Lombardi, P., Giordano, S., Caragliu, A., Del Bo, C., Deakin, M., Nijkamp, P., & Kourtit, K. (2011). An advanced triple-helix network model for smart cities performance. *Vrije Universiteit Amsterdam, Research Memorandum 2011-45*http://degree.ubvu.vu.nl/repec/vua/wpaper/pdf/20110045.pdf (accessed 23.2.2016)
Lombardi, P., Giordano, S., Farouh, H., & Yousef, W. (2012). Modelling the smart city performance. *Innovation: The European Journal of Social Science Research*, *25*(2), 137–149.
Marsal-Llacuna, M. -L., & Segal, M. E. (2016). The Intelligenter Method (I) for making "smarter" city projects and plans. *Cities*. http://dx.doi.org/10.1016/j.cities.2016.02.006.
Marsal-Llacuna, M. -L., Colomer-Llinàs, J., & Meléndez-Frigola, J. (2015). Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative. *Technological Forecasting and Social Change*, *90*(B), 611–622. http://dx.doi.org/10.1016/j.techfore.2014.01.012.
McKinsey & Company (2011). Economic development and sustainability must go hand in hand. http://mckinseyonsociety.com/sustainable-cities-initiative/ (accessed 23.2.2016)
McManus, P. (2012). Measuring urban sustainability: The potential and pitfalls of city rankings. *Australian Geographer*, *43*(4), 411–424. http://dx.doi.org/10.1080/00049182.2012.731301.
Mercer (2014). 2014 Quality of Living worldwide rankings – Mercer Survey. New York. http://www.uk.mercer.com/newsroom/2014-quality-of-living-survey.html (accessed 23.2.2016)
Ministère de l'Égalité des territoires et du Logement (2014). Reference framework for European sustainable cities (RFSC). http://www.logement.gouv.fr/IMG/pdf/le_cadre_de_reference_de_la_ville_europeenne_durable_rfsc_-_version_anglaise.pdf (accessed 14.4.2016)
Monfaredzadeh, T., & Berardi, U. (2015). Beneath the smart city: Dichotomy between sustainability and competitiveness. *International Journal of Sustainable Building Technology and Urban Development*, *6*(3), 140–156. http://dx.doi.org/10.1080/2093761X.2015.1057875.
Monocle (2014). Quality of Life Survey 2013. http://monocle.com/film/affairs/quality-of-life-survey-2013/ (accessed 23.2.2016)
Murphy, K. (2012). The social pillar of sustainable development: A literature review and framework for policy analysis. *Sustainability: Science, Practice & Policy*, *8*(1), 15–29http://sspp.proquest.com/static_content/vol8iss1/1008-041.murphy.pdf (accessed 23.2.2016)
Nam, T., & Pardo, T. A. (2011). *Conceptualising smart city with dimensions of technology, people and institutions* (pp. 282–291)Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times.
Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., & Scorrano, F. (2014). Current trends in Smart City initiatives: Some stylised facts. *Cities*, *38*, 25–36. http://dx.doi.org/10.1016/j.cities.2013.12.010.
Nilon, C., Berkowitz, A., & Hollweg, K. (2003). Introduction: Ecosystem understanding is a key to understanding cities. In A. Berkowitz (Eds.), *Understanding urban ecosystems. A new frontier for science and education* (pp. 1–14). Springer.
Nixon, J. (2009). *Sustainable economic development: Initiatives, programs and strategies for cities and regions. Urban Sustainability Associates.* Sustainable Systems, Inchttp://www.globalurban.org/Sustainable%20Economic%20Development.pdf (accessed 23.2.2016)
OECD (2012). *OECD environmental outlook to 2050. The consequences of inaction.* OECD Publishinghttp://www.naturvardsverket.se/upload/miljoarbete-i-samhallet/internationellt-miljoarbete/multilateralt/oecd/outolook-2050-oecd.pdf (accessed 23.2.2016)
Paroutis, S., Bennett, M., & Heracleous, L. (2013). A strategic view on smart city technology: The case of IBM Smarter Cities during a recession. *Technological Forecasting and Social Change*, *89*, 262–272. http://dx.doi.org/10.1016/j.techfore.2013.08.041.
Post Carbon Cities (2007). Preparing local governments for energy and climate uncertainty. http://postcarboncities.net/how-green-your-city-sustainlane-us-city-rankings (accessed 23.2.2016)
Reed, B. (2007). Shifting from 'sustainability' to regeneration. *Building Research and Information*, *35*(6), 674–680. http://dx.doi.org/10.1080/09613210701475753.
Reed, M., Fraser, E., & Dougill, A. (2006). An adaptive learning process for developing and applying sustainability indicators with local communities. *Ecological Economics*, *59*, 406–418. http://dx.doi.org/10.1016/j.ecolecon.2005.11.008.
Robinson, J., & Cole, R. (2015). Theoretical underpinnings of regenerative sustainability. *Building Research and Information*, *43*(2), 133–143. http://dx.doi.org/10.1080/09613218.2014.979082.
Salat, S., & Bourdic, L. (2012). Systemic resilience of complex urban systems. *TeMA-Trimestrale del Laboratorio Territorio Mobilità e Ambiente-TeMALab*, *5*(2), 55–68. http://dx.doi.org/10.6092/1970-9870/918.
Segnestam, L. (2002). Indicators of environment and sustainable development. Theories and practical experience. *The World Bank Environment Department. Environmental Economics Series. Paper No. 89. December 2002. Washington, USA* Accessed (15.5.2016) http://siteresources.worldbank.org/INTEEI/936217-1115801208804/20486265/IndicatorsofEnvironmentandSustainableDevelopment2003.pdf
Sharifi, A., & Murayama, A. (2013). A critical review of seven selected neighborhood sustainability assessment tools. *Environmental Impact Assessment Review*, *38*, 73–87. http://dx.doi.org/10.1016/j.eiar.2012.06.006.
Shelton, T., Zook, M., & Wiig, A. (2015). The 'actually existing smart city'. *Cambridge Journal of Regions, Economy and Society*, *8*, 13–25. http://dx.doi.org/10.1093/cjres/rsu026.
Smart City PROFILES (2013). Ergebnisse. 7.6.2013. http://www.smartcities.at/assets/03-Begleitmassnahmen/SmartCity-PDF-INTRO.pdf (accessed 23.2.2016)
Söderström, O., Paasche, T., & Klauser, F. (2014). Smart cities as corporate storytelling. *City*, *18*(3), 307–320. http://dx.doi.org/10.1080/13604813.2014.906716.
Sustain Lane Criteria (d). Green & sustainable draft recommendations. http://www.downtowndayton.org/pdfs/recommendations_green_appendix1.pdf (accessed 23.2.2016)
Tanguay, G. A., Rajaonson, J., Lefebvre, J. -F., & Lanoie, P. (2010). Measuring the sustainability of cities: An analysis of the use of local indicators. *Ecological Indicators*, *10*, 407–418. http://dx.doi.org/10.1016/j.ecolind.2009.07.013.
Turcu, C. (2013). Re-thinking sustainability indicators: Local perspectives of urban sustainability. *Journal of Environmental Planning and Management*, *56*(5), 695–719. http://dx.doi.org/10.1080/09640568.2012.698984.
UCLG (2012). Smart Cities Study: International study on the situation of ICT, innovation and knowledge in cities. Bilbao. http://www.cities-localgovernments.org/committees/cdc/Upload/formations/smartcitiesstudy_en.pdf (accessed 23.2.2016)
United Nations (1992). Agenda 21. United Nations Conference on Environment & Development. Rio de Janerio, Brazil, 3 to 14 June 1992. https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf (accessed 3.6.2016)
United Nations (2015a). *World urbanization prospects. The 2014 revision.* New York: Department of Economic and Social Affairshttp://esa.un.org/unpd/wup/Publications/Files/WUP2014-Report.pdf (accessed 22.5.2016)
United Nations (2015b). *Habitat III issue papers, 21 – Smart cities. V. 2.0 (31 May 2015), issued in New York, USA, by UN task team on Habitat III, a task force of UN agencies and programs for the New Urban Agenda, prepared for Habitat III United Nations Conference on Housing and Sustainable Urban Development to take place in Quito, Ecuador, 17–20 October 2016.*
United Nations (2016). Paris agreement. United Nations treaty collection, reference C.N.63.2016.TREATIES-XXVII.7.d. Agreement adopted at the twenty-first session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, in Paris from 30 November to 13 December 2015. https://treaties.un.org/doc/Publication/CN/2016/CN.63.2016-Eng.pdf (accessed 21.6.2016)
United Nations Human Settlements Programme (2004). Urban indicators guidelines. Monitoring the habitat agenda and the millennium development goals. http://ww2.unhabitat.org/programmes/guo/documents/urban_indicators_guidelines.pdf (accessed 23.2.2016)
Vallance, S., Perkins, H. C., & Dixon, J. E. (2011). What is social sustainability? A clarification of concepts. *Geoforum*, *42*(3), 342–348. http://dx.doi.org/10.1016/j.geoforum.2011.01.002.
Vanolo (2014). Smartmentality: The smart city as disciplinary strategy. *Urban Studies*, *51*(5), 881–896. http://dx.doi.org/10.1177/0042098013494427.
Vanolo, A. (2015). The image of the creative city, eight years later: Turin, urban branding and the economic crisis taboo. *Cities*, *46*, 1–7. http://dx.doi.org/10.1016/j.cities.2015.04.004.
Wall, R., & Stravlopoulos, S. (2016). Smart cities within world city networks. *Applied Economics Letters*. http://dx.doi.org/10.1080/13504851.2015.1117038.
Washburn, D., Sindhu, U., Balaouras, S., Dines, R. A., Hayes, N., & Nelson, L. E. (2010). *Helping CIOs understand "smart city" initiatives: Defining the smart city, its drivers, and the role of the CIO.* Cambridge, MA: Forrester Research, Inchttps://www.forrester.com/Helping+CIOs+Understand+Smart+City+Initiatives/fulltext/-/E-RES55590 (accessed 23.2.2016)
WCED (The World Commission on Environment and Development) (1987)). Report of the World Commission on Environment and Development: Our common future. United Nations. http://www.un-documents.net/our-common-future.pdf (accessed 23.2.2015)
Zhang, X. (2012). *Smart cities benchmarking in China.* China: Ministry of Industry and Information Technology (MIIT)http://www.probe-it.eu/wp-content/uploads/2012/06/3-IoTweek-benchmarking-XZhang.pdf (accessed 23.2.2016)