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What are the differences between sustainable and smart cities?

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Highlights

- We studied the differences of smart and sustainable city performance assessment
- We analyzed 16 sets of city assessment frameworks (smart and sustainable)
- Smart city frameworks focus mainly on social and economic sustainability
- We recommend the use of a more accurate term “smart sustainable cities”

What are the differences between sustainable and smart cities?

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.

Key words: smart city, sustainable city, indicator, assessment framework, performance measurement

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 et al., 2015). However, these are interconnected and often smart cities share similar goals as sustainable cities. A large variety of smart city definitions exist (Albino et al., 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 et al., 2016).

In European Union's view (2012) 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 and 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 CO₂ reduction targets such as the European Union 2030 targets. Tools are needed 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 et al. (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 et al. (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 et al. (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 et al. (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".

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 et al., 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 et al., 2011; Hollands, 2008; Marsal-Llacuna et al., 2015; Wall and Stavropoulos, 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 and Rossi, 2011; Harrison and Donnely, 2011; Hung-Nien et al., 2011; Jucevicius et al., 2014; Paroutis et al., 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 et al., 2014; Giffinger et al., 2007; Hollands, 2008; Nam and 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 et al. 2016 and Lee et al. (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. (2013) 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 et al., (2012). Specific frameworks and indicators to benchmark cities according to the smartness of their transportation systems have been proposed by Debnath et al. (2014) and Garau et al. (2016).

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).

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

Name of the framework	Description	Source	Number of Categories Indicators
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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 analysing 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

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

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 (Tuanguay et al., 2010). However, weighting is not considered in our study because we are only interested about measuring the coverage to specific aspects or issues, not assessing how each indicator contribute to the final result relative to the purpose of the specific performance measurement system. Also, weights were not part of many of the frameworks analyzed. Exploring the indicators of an assessment system 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 et al., 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 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*.

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. 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 of the 958 indicators, 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.

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%).

		Impact categories			
		Environmental sustainability	Economic sustainability	Social sustainability	<i>In total</i>
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 %
		<i>In total</i>	20 %	28 %	52 %

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	<i>In total</i>
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 %
		<i>In total</i>	43 %	10 %	47 %

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

3.2. Comparison of the two types of assessment frameworks

Figure 1 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.

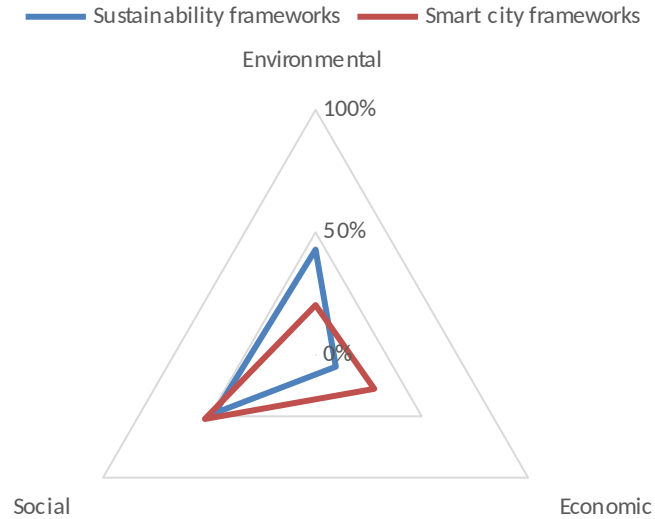


Figure 1. Division of the number of indicators for both smart city urban sustainability frameworks under the three dimensions of sustainability.

As can be observed in figure 1, 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.

Division of indicators under the social dimension of sustainability

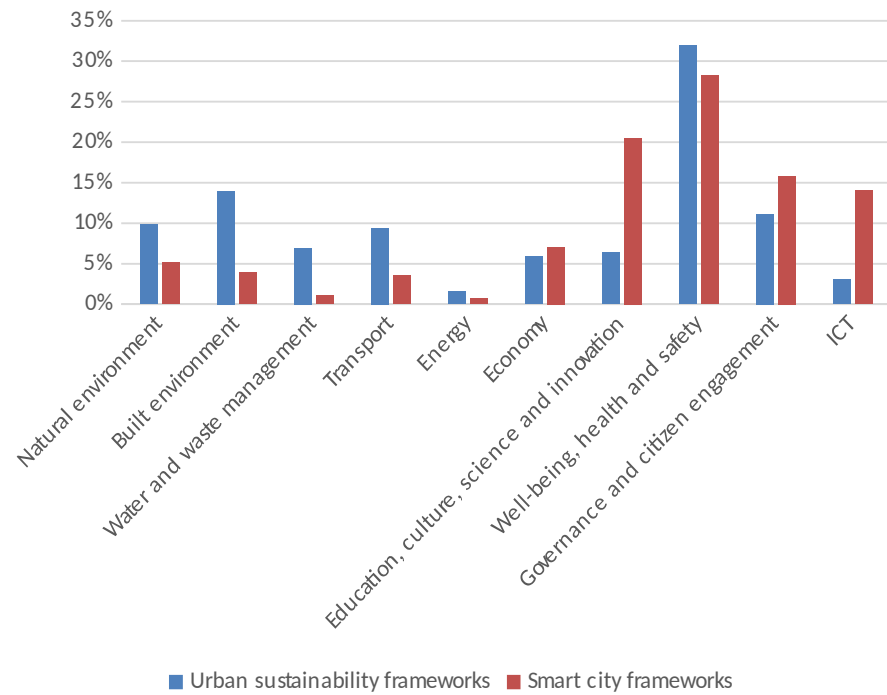


Figure 2. Division of the sustainable and smart indicators under different sectors within the social dimension.

How the 10 sectors are covered in total by the two types of frameworks is illustrated in figure 3 (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.

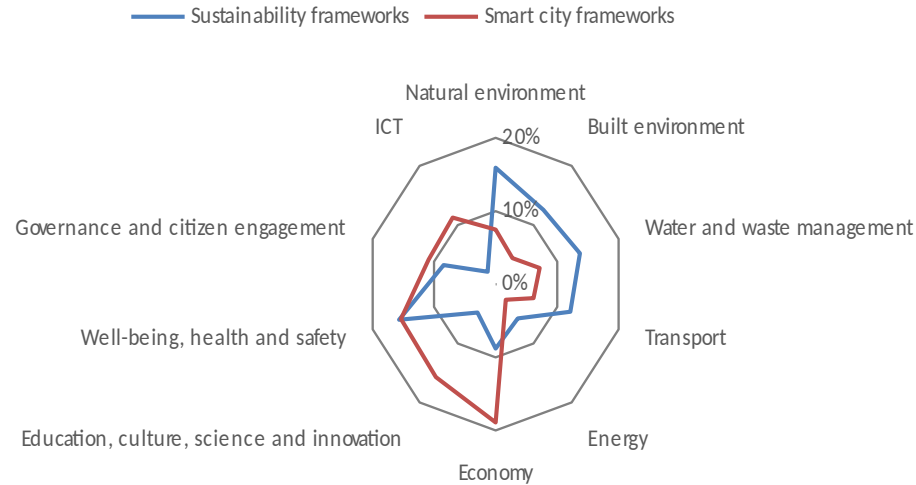


Figure 3. Division of the indicators of both smart city urban sustainability frameworks under the ten sector categories.

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. 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 attention (for example Vallance et al., 2011; Murphy, 2012) and possibilities for citizens to participate for example in urban planning have been minor (e.g. Kathlene and 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, 2011).

However, the small number of environmental indicators in the smart city frameworks is a remarkable deficiency because reducing energy consumption and CO₂ 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. Conclusion

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 analyzed smart city frameworks 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 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.(2015), not in the new technology as an end in itself (Marsal-Llacuna and 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 et al., 2015; Söderström et al., 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 et al. (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-CENELC-ETSI, 2016) 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.

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								
	Ranking1. European Smart City	2. Smart cities wheel	3. Bilbao Smart cities study	4. Smart cities benchmarking	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
<i>Distributing the points among sectors*</i>																		
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

* 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.