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SMART AND SUSTAINABLE CITIES: IN SEARCH OF COMPREHENSIVE THEORETICAL FRAMEWORK

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Abstract: The article delivers the results of systematic literature review of research on smart and sustainable cities. An overview of definitions, dimensions and components of smart city, sustainable city and smart sustainable city was presented. In addition, the identification of existing methods and indicators used for rating smart cities and sustainable cities was performed. Based on analysis of complexity and thoroughness of the identified assessment frameworks, methodologies that can be used for comprehensive evaluation of the smart sustainable city were determined. Finally, the identified research gaps and issues with potential future contribution within analyzed scientific area were indicated.

Keywords: smart city, sustainable city, smart sustainable city, literature review.

1. Introduction

The urban population of the world has grown rapidly since 1950, having increased from 751 million to 4.2 billion in 2018. This means that 55% of the world's population lived in urban areas in 2018. In addition, it is estimated that this percentage will continue to rise and will reach 68% in 2050 (UN, 2019). The increasing number of people residing in urban areas will undoubtedly escalate the environmental problems that cities are already facing up. These problems mainly result from the significant consumption of resources and energy, the amount of pollutants emitted from cars and heating systems used in households, as well as from a large amounts of generated waste. The growing number of people living in urban areas has also a significant effect on urban services and infrastructure that reaches or exceeds its limits in many cities. In order to manage these problems, it became necessary to change the approach to designing city development. It is expected that cities are to develop continually, but in such a way as to have the least possible impact on the quality of the environment and

ensure the improvement of the quality of life of inhabitants. This means that cities are to grow in accordance with the concept of sustainable development. Moreover, intelligent solutions should be introduced in cities that would improve the functioning of urban infrastructure and thus would have a positive impact on the quality of life of local communities. Therefore, cities should be smart and sustainable at the same time.

The concept of the smart sustainable city is a relatively new phenomenon that has become widespread over the past few years. Unfortunately, there is a lack of one generally accepted definition of this concept. A numerous methods and indicators have been developed to assess whether the city is smart or sustainable. However, it seems to be evident that the smart sustainable city lacks a commonly shared theoretical framework.

For this reason, this article presents the results of systematic literature review on smart and sustainable city. In particular, it aims at identification of definitions, dimensions and components of smart city, sustainable city and smart sustainable city as well as at indication of existing methods and indicators used for rating smart cities and sustainable cities. In addition, based on Delphi methodology the most comprehensive methodologies that can be used for evaluation of the smart sustainable city were determined.

The identification of definitions, dimensions and components of smart city, sustainable city and smart sustainable city as well as the existing methods and indicators used for rating smart cities and sustainable cities was based on the search of articles, conference papers, studies and reports via Web of Science, Scopus and Google Scholar. Different options of the query wording were used for the database search in title, abstract and keywords fields of relevant publications. These wordings included: ‘sustainable urban‘, ‘city sustainability‘, ‘urban sustainability‘, ‘sustainable urban development‘, ‘sustainable city development‘, ‘digital city/cities‘, ‘intelligent city/cities‘, ‘smart city/cities‘, ‘smart sustainable city/cities‘, ‘sustainable smart city/cities‘, ‘smart and sustainable city/cities‘, ‘sustainable and smart city/cities‘, ‘definition‘, ‘dimension‘, ‘assessment’, ‘evaluation’, ‘tool’, ‘measure’, ‘metrics’. In the next step, the relevant references related to definitions, dimensions and components of smart city, sustainable city and smart sustainable city as well as publications describing methods and indicators used for rating smart cities and sustainable cities were explored. Based on this analysis the most commonly used definitions and dimensions of smart city, sustainable city and smart sustainable city were identified. Next, the existing methods and indicators used for the assessment of smart cities and sustainable cities were indicated. The analysis of complexity and thoroughness of relevant assessment frameworks revealed the most comprehensive methodologies that can be used for evaluation of the smart sustainable city were determined. These methods were assessed according to the Delphi methodology. Finally, the identified research gaps and issues with potential future contribution within analyzed scientific area were presented.

2. Literature review on smart and sustainable city definitions

2.1. The essence of smart city

The term 'smart city' was first used in the early 1990s in connection with growing significance of new ICT with regard to modern infrastructures within cities. It has gained greater attention since 2008, with the launch of IBM's Smarter Planet project (Harrison et al., 2010). Since then, this concept has continued to grow and evolve resulting in a variety of smart city definitions. However, there is no universally agreed upon definition of smart city and this is a multifaceted, wide-ranging and a fuzzy notion that is used in ways that are not always consistent. The examples of smart city definitions are presented in Table 1.

Table 1.
The examples of smart city definitions

Author of definition	Definition of smart city
Hall et al. (2000)	A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens.
Giffinger et al. (2007)	A city well performing in a forward-looking way in economy, people, governance, mobility, environment and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens.
Rios (2008)	A city that gives inspiration, shares culture, knowledge, and life, a city that motivates its inhabitants to create and flourish in their own lives. A smart city is an admired city, a vessel to intelligence, but ultimately an incubator of empowered spaces.
Harrison et al. (2010)	An instrumented, interconnected and intelligent city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city.
Caragliu et al. (2011)	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.
Kourtit and Nijkamp (2012)	The result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance. A city based on a promising mix of human capital (e.g. skilled labor force), infrastructural capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities).
Lazaroiu and Roscia (2012)	A city model where the technology is in service to the person and to his economic and social life quality improvement. A solution that considers electricity, water and gas consumption, as well as heating and cooling systems, public safety, waste management and mobility.

It seems to be evident that smart city lacks a commonly shared definition. Nevertheless, there are two mainstream approaches to this concept: the technology and ICT-oriented approach and the people-oriented approach. This means that smart city policy focuses on the efficiency and advancement of hard infrastructure and technology (transport, energy, communication, waste, water, etc.) through ICT and/or it is concentrated on the soft infrastructure and people

(i.e. social and human capital in terms of knowledge, participation, equity, safety, etc.). (Angelidou, 2014). However, the importance of citizens perspective in the development of smart cities is often overlooked and even ignored (Hollands, 2008).

It must be noted that several similar to smart city terms are often used interchangeably. These concepts include: digital cities, virtual cities, cyber cities, networked cities, intelligent cities, knowledge cities, ubiquitous cities, real–time cities, and hybrid cities which combine two or more of these names (Bibri, and Krogstie, 2017b). However, these terms refer to more specific aspects of a city (Janik, and Ryszko, 2018), so that the concept of smart city is broaden and often includes them (Albino et al., 2015) and focus on other issues (Meijer, and Bolivar, 2016).

2.2. The concept of sustainable city

The concept of a sustainable city is derived from the concept of sustainable development, which means development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). The cities due to the large accumulation of people and their activities cause significant energy consumption, air pollution and the production of sewage and solid waste which has a significant impact on the quality of the environment and thus on the quality of human life. For that reason, it has become so important to take into account the principles of sustainable development in planning city development.

The term ‘sustainable city’ emerged in literature in early 1990s (Bibri, and Krogstie, 2017b). Unfortunately, due to the lack of one accepted definition of sustainable development (even a definition published in 1987 in the Brundtland Report is controversial for some authors (Molnar et al., 2001)), also the concept of sustainable city does not have one common definition. In addition, there are also several similar terms often used interchangeably. These concepts comprise: sustainable urban, city sustainability, urban sustainability, sustainable urban development, sustainable city development. The examples of sustainable city definitions are presented in Table 2.

Table 2.
The examples of sustainable city definitions

Author of definition	Definition of sustainable city
Ewers and Nijkamp (1990)	A city which has a potential to reach qualitatively a new level of socio-economic, demographic and technological output which in the long run reinforces the foundations of the urban system.
Jenks et al. (1996)	A city in the state of continuous dynamic balance seeking among its environmental, social, and economic attributes.
Girardet (1999)	A city which is organized so as to enable all its citizens to meet their own needs and to enhance their well-being without damaging the natural world or endangering the living conditions of other people, now or in the future.
Castells (2000)	A city where conditions of its production do not destroy the conditions of its reproduction over time.

Cont. table 2.

United Nations (2013)	A city which is built on social development, economic development, environmental management and urban governance to ensure having "low ecological footprint" and eliminate transferring economic, social and environmental hazards to other locations and future generations.
Hiremath et al. (2013)	A city that has achieved a balance between urban development and environmental protection, including equality of income, employment, shelter, basic services, social infrastructure and transport in urban areas.
Blanco and Mazmanian (2015)	A city which is ecologically sustainable, socially just and economically viable and which is an active, evolving, organic community addressing problems of the present and foreseeable future while confronting ongoing challenges of economic development, equity and justice and environmental protection.
Ibrahim et al. (2015)	A city that can secure now and in the future the basic needs of city inhabitants such as infrastructure, civic amenities, health and medical care, housing, education, transportation, employment, good governance and ensure the populations needs are met benefiting all sectors of society.
Gardner (2016)	A vibrant human settlement that provides ample opportunities, in harmony with the natural environment, to create dignified lives for all citizens
Bibri and Krogstie (2017b)	A desired state of city in which the urban society strives for achieving a balance between environmental protection and integration, economic development and regeneration, and social equity and justice within cities.
Wang et al. (2019)	A city where the quality of life has improved including ecological, cultural, political, institutional, social and economic components without leaving a burden on the future generations.

The presented definitions show that sustainable city integrates environmental, economic and social considerations in order to achieve the goals of sustainable development. It is a compact urban form which ensures greater efficiency and innovation capacity at lower costs and reduced environmental impact. A sustainable city provides a safe and healthy urban environment where both people and nature can develop. Such a city is also expected to have a local government with the fiscal and administrative capacity to fulfill its urban functions with active participation of citizens (Global Platform for Sustainable Cities, 2018).

2.3. Smart sustainable city – definitions and general characteristics

The smart sustainable city is a new phenomenon and this term became widespread during the mid–2010s. Höjer and Wangel (2015) identified five developments that can be seen as the seeds from which the concept of smart sustainable city has grown. These issues include: globalization of environmental problems and sustainable development, urbanization and urban growth, sustainable urban development and sustainable cities, information and communication technologies, and smart cities.

The combination of smart city and sustainable city is conceptually difficult to describe and it has been less explored due to the multiplicity and diversity of the existing definitions of smart city and sustainable city. However, the term 'smart sustainable city' is generally used to denote a city that is supported by a pervasive presence and massive use of advanced ICT, which, in connection with various urban domains and systems and how these intricately interrelate, enables cities to become more sustainable and to provide citizens with a better quality of life

(Bibri, and Krogstie, 2017a). The examples of smart sustainable city definitions are presented in Table 3.

Table 3.
The examples of smart sustainable city definitions

Author of definition	Definition of smart sustainable city
ITU (2014)	An innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.
Höjer and Wangel (2015)	A city that meets the needs of its present inhabitants without compromising the ability for other people or future generations to meet their needs, and thus, does not exceed local or planetary environmental limitations, and where this is supported by ICT.
Dhingra and Chattopadhyay (2016)	A city characterized as the one with following goals to be achieved in an adaptable, reliable, scalable, accessible and resilient manner: (1) improve quality of life of its citizens, (2) ensure economic growth with better employment opportunities, (3) improve well-being of its citizens by ensuring access to social and community services, (4) establish an environmentally responsible and sustainable approach to development, (5) ensure efficient service delivery of basic services and infrastructure such as public transportation, water supply and drainage, telecommunication and other utilities, (6) ability to address climate change and environmental issues, and (7) provide an effective regulatory and local governance mechanism ensuring equitable policies.
Bibri and Krogstie (2017a)	A dynamic, complex interplay between scientific innovation, technological innovation, environmental innovation, urban design and planning innovation, institutional innovation, and policy innovation. It represents and involves inherently complex socio-technical systems of all sorts of innovation systems. Such systems, which focus on the creation, diffusion, and utilization of knowledge and technology, are of various types (variants of innovation models), including national, regional, sectoral, technological, and Triple Helix of university–industry–government relations.
Bibri and Krogstie (2017b)	A social fabric made of a complex set of networks of relations between various synergistic clusters of urban entities that, in taking a holistic perspective converge on a common approach into using and applying smart technologies to develop, use, disseminate, and mainstream innovative solutions and sophisticated methods that help provide a fertile environment conducive to advancing sustainability by strategically assessing and continuously enhancing the contribution to the goals of sustainable development.
Bibri (2018)	A holistic urban development approach which seeks to explicitly bring together sustainable city and smart city as urban endeavors in ways that address and overcome the key shortcomings of both classes of cities in terms of their contribution to the goals of sustainable development.

The field of smart sustainable city is inherently interdisciplinary, comprising technological, social, environmental, economic, cultural and philosophical perspectives. This is due to the fact that it covers multidimensional issues related to interlinked development of sustainability awareness, rapid urban growth and technological development. However, research on smart sustainable cities is in its early stages. Therefore, the concept of a smart sustainable city needs thorough clarification and operationalization of its characteristics. Nevertheless, smart sustainable city means that smart city must contribute to sustainability, including the

environmental, economic and social goals of sustainable development. In this regard, Kramers et al. (2014) suggest that the concept of smart sustainable city should be understood as a way of emphasizing initiatives when smartness is (also) used to promote sustainability. In addition, Höjer and Wangel (2015) claim that smart city becomes sustainable when ICT is employed for improving sustainability.

3. Conceptual frameworks of smart and sustainable city – analysis results of identified dimensions and components

3.1. Identification of dimensions and components of smart city

There are various dimensions and components of a smart city. Mahizhnan (1999) described smart city using four dimensions: IT education, IT infrastructure, IT economy and quality of life. Giffinger et al. (2007) presented a hierarchic structure of smart city depicted by 6 main characteristics, 33 factors and 74 indicators. These characteristics comprised: smart economy (competitiveness), smart people (social and human capital), smart governance (participation), smart mobility (transport and ICT), smart environment (natural resources) and smart living (quality of life). Considering the performance of a smart city, Lombardi et al. (2012) proposed the framework linking the six dimensions of smart city suggested by Giffinger et al. with the revised classical triple helix model (i.e. four helices – university, government, civil society and industry). Eger (2009) suggested that smart city contains the following dimensions: technology, economic development, job growth and increased quality of life. Nam and Pardo (2011) created a conceptual model of a smart city embracing three categories of core components: technology (infrastructures of hardware and software), people (creativity, diversity, and education), and institution (governance and policy). These components were linked with the strategic principles to make a city smart: integration of technology factors, learning for human factors and governance of institutional factors. Kourtit and Nijkamp (2012) outlined four dimensions of smart city, including human capital (e.g. skilled labor force), infrastructural capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages), and entrepreneurial capital (e.g. creative and risk-taking business activities). Neirotti et al. (2014) elaborated a taxonomy of six main domains and the associated sub-domains of smart city deployment. These domains comprise: natural resources and energy (i.e. smart grids, public lighting, green/renewable energies, waste management, water management, food and agriculture), transport and mobility (i.e. city logistics, info-mobility, people mobility), buildings (i.e. facility management, building services, housing quality), living (i.e. entertainment, hospitality, pollution control, public safety, healthcare, welfare and social inclusion, culture, public spaces management), government (i.e. e-government, e-democracy, procurement, transparency), as well as economy and people (i.e. innovation and

entrepreneurship, cultural heritage management, digital education, human capital management).

Caragliu et al. (2011) summarized the characteristics proper to a smart city that tend to be common to many of the previous findings as follows: (1) utilization of networked infrastructure to improve economic and political efficiency and enable social, cultural and urban development, (2) emphasis on business-led urban development, (3) a strong focus on the aim to achieve the social inclusion of various urban residents in public services, (4) a stress on the crucial role of high-tech and creative industries in long-run urban growth, (5) profound attention to the role of social and relational capital in urban development, and (6) social and environmental sustainability as a major strategic component of smart cities.

3.2. Identification of dimensions and components of sustainable city

Understanding the dimensions and components of sustainable city is a complex issue because cities differ in geography, climate, culture, history, wealth and a host of other dimensions (Gardner, 2016). There are various different dimensions and components of a sustainable city in the literature. However, based on the paradigm of sustainability, the three main dimensions of a sustainable city are most often indicated: (1) environmental, (2) social and (3) economic. Some authors add one or more dimensions to the dimensions listed above. Estevez et al. (2016) consider that a city is sustainable if it promotes such dimensions of sustainable development as: (1) economic – a city with a healthy, dynamic and responsible economy, (2) social – a city promoting social inclusion and quality of life of its residents, (3) environmental – a city adopting ecological practices to protect its environment, and (4) institutional – a city governed in transparent ways, while engaging its residents. Bibri and Krogstie (2017b) indicate the following dimensions of a sustainable city: the form (size, shape, land uses, configuration and distribution of open space, etc.), the environment, the economy, and equity. According to Baldimer et al. (2013), a city which wants to be sustainable needs to meet social, environmental, political and cultural objectives as well as economic and physical ones. Jarrar and Al-Zoabi (2008) believe that in addition to environmental, social and economic attributes, also parameters (i.e. main principles), criteria (i.e. the statements reflecting the requirements for achieving the goal) and indicators (representing quantifiable data) should be listed as dimensions of a sustainable city. Global Platform for Sustainable Cities (2018) distinguishes the following pillars of a sustainable city: (1) social development including: education and health, food and nutrition, green housing and buildings, water and sanitation, green public transportation, green energy access, recreation areas and community support, (2) economic development including: green productive growth, creation of decent employment, production and distribution of renewable energy, technology and innovation (R&D), (3) environmental management including: forest and soil management, waste and recycling management, energy efficiency, water management, air quality conservation, adaptation to and mitigation of climate change, and (4) urban governance

including: planning and decentralization, reduction of inequities, strengthening of civil and political rights, support of local, national, regional and global links.

3.3. Identification of dimensions and components of smart sustainable city

There are numerous frameworks that can be used to characterize either the smartness or the sustainability of the city. Although some research focuses on developing integrated approaches that combine these two constructs, studies in this area remains very scant. In fact, certain attempts were made to build the comprehensive framework that can tackle the dimensions of smart sustainable city.

Bibri and Krogstie (2017b) claim that the typically complex, diverse sets of socio-technical systems underlying smart sustainable cities entail different elements of innovation in the form of smartness and development across many urban domains (transport, environment, energy, healthcare, education, planning, etc.) for the purpose of advancing sustainability and integrating its dimensions. Based on a detailed analysis of the keywords in 116 definitions of a smart and sustainable city ITU-T Focus Group on Smart Sustainable Cities conceptualized the key categories that best define a smart sustainable city. These key categories include: (1) ICT, communication, intelligence and information, (2) infrastructure and services, (3) environment and sustainability, (4) people, citizens and society, (5) quality of life and lifestyle, (6) governance, management and administration, (7) economy and finance, and (8) mobility. In addition, the following categories based on analyzed key indicators were indicated: smart living, smart people, smart environment and sustainability, smart governance, smart mobility, and smart economy (ITU, 2014). Monfaredzadeh and Berardi (2015) identified and compared existing methods and indicators used in rating systems for smart city, sustainable city and competitive city to figure out what these concepts seek to achieve and where they complement and contrast. Based on this analysis they distinguished 9 key fields of smart sustainable city which are as follows: natural environment, built environment, water and waste management, energy, transport, economy, welfare and health, education and culture, and governance.

Considering standardized approaches to the assessment of smart and sustainable city, the ISO 37122 outlines the following main categories describing smart city that increases the pace at which it provides social, economic, and environmental sustainability outcomes (in fact, this means smart sustainable city): economy, education, energy, environment and climate change, finance, governance, health, housing, population and social conditions, recreation, safety, solid waste, sport and culture, telecommunication, transportation, urban/local agriculture and food security, urban planning, wastewater, and water. ITU (2016) proposes, in turn, that sustainability of a smart city is based on five main aspects: (1) economic (the ability to generate income and employment for the livelihood of the inhabitants, (2) social (the ability to ensure that the welfare (safety, health, education, etc.) of the citizens can be equally delivered despite differences in class, race or gender), (3) environmental (the ability to protect future quality and reproducibility of natural resources), (4) governance (the ability to maintain social

conditions of stability, democracy, participation and justice), and (5) cultural (the ability to promote cultural identity and adequacy, value and emotional well-being).

4. Analysis results of methods and indicators for assessing smart and sustainable cities

4.1. Identification of methods and indicators for assessing smart cities

The smart city assessment methodology is now one of the most dynamically developed research areas. However, the literature review indicates that there is no universal method of such evaluation.

There are many original methods for assessing the smart city performance. The most comprehensive ones include: Smart City PROFILES, City Protocol, European Smart City Ranking and methods using the Key Performance Indicator (KPI) concept, in particular: Collection Methodology for the KPI for Smart Sustainable Cities, Conceptual Smart City KPI Model, KPI Selection to Assess Smart City Solutions, CITYkeys indicators, and Triple-helix network model for smart cities performance.

Most methods are based on a well-established concept (they are developed once and do not change over time). However, as there is no unified smart city definition and considering that the notion is evolving dynamically, a need arises to continuously improve methods of the smartness level assessment. One of such methods is Smart Cities Wheel.

Some methods are described in normative documents developed and evolved by standardization bodies, such as the International Organization for Standardization (ISO), the International Telecommunication Union (ITU), and the European Telecommunications Standards Institute (ETSI). These institutions have established the following standards that can be used as comprehensive frameworks of the smart city assessment: ISO 37122:2019 Sustainable cities and communities. Indicators for smart cities; ITU-T Y.4903/L.1603 Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals; ETSI TS 103 463 Access, Terminals, Transmission and Multiplexing (ATTM); Key Performance Indicators for Sustainable Digital Multiservice Cities. It must be noted that the above mentioned documents are systematically updated.

The methods are universal in nature although some are designed for specific regions, e.g. the Bilbao Smart Cities Study or the Smart City Benchmarking in China.

The methods for assessing the smart city performance differ in terms of numbers of dimensions and indicators as well as levels of indicators aggregation. For example, the CITYkeys method makes it possible to assess up to 20 dimensions. However, this does not mean that it is the most comprehensive one because the range of the assessment methods depends primarily on the scope of indicators that are listed in the lowest level of aggregation of

the relevant method components. There are usually two aggregation levels of indicators, however European Smart Cities Ranking and Smart City Wheel have three. The former makes use of 74 indicators aggregated into 31 factors and 6 categories, whereas the latter uses 62 indicators, 18 working areas and 6 dimensions. The methods for assessing the smart cities have up to 190 indicators (City Protocol) but there are also methods with only 21 measures (Smart City PROFILES).

4.2. Identification of methods and indicators for assessing sustainable cities

Due to the lack of one generally accepted definition and dimensions of a sustainable city, there are many methods and tools used to assess sustainable cities. These methods are usually based on the assessment of various sets of indicators, the number and type of which depends on the adopted assessment objective, as well as the number of dimensions of the city covered by the assessment. There are methods that measure the current development of the city and its progress in implementing the principles of the sustainable development. Examples of these methods are: Reference Framework for Sustainable Cities, UN-Habitat City Prosperity Index or Urban sustainability assessment frameworks. There are also methods used to rank and to compare different cities in terms of sustainable development. Examples of these methods include: Arcadis Sustainable Cities Index, Sustainability Tools for Assessment and Rating Communities or The Global Power City Index. Methods for assessing sustainable cities also include measures which are used for assessing sustainable neighborhoods like: LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Assessment Method), CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) or DGNB (German Sustainable Building Council). Considering these methods, multi-criteria assessment of buildings and their surrounding is carried out in terms of achieving sustainable development goals.

Another group of methods for assessing sustainable cities are the ones measuring urban quality of life. An example of these methods can be the following: Global Liveability Ranking published annual by the Economist Intelligence Unit, Mercer Quality of Living Survey, Monocle's "Most Liveable Cities Index". It should be noted that these methods focus primarily on assessing the social and environmental dimensions of urban life and rarely take into account all dimensions of sustainable development. In addition to these measures, there are also methods that take into account only the environmental dimension. These are as follows: the European Green Capital Award, the Green City Index and the Urban Ecosystem Europe.

The methods mentioned above allow to assess selected dimensions of a sustainable city. However, they differ in the context of assessment comprehensiveness and in-depth analysis. In fact, they comprise between 3 and 19 dimensions of a sustainable city. The examples of these methods are: Arcadis Sustainable Cities Index (3 dimensions), Sustainability Assessment Tool for Urban Planning (4 dimensions), Reference Framework for Sustainable Cities (5 dimensions), Urban sustainability assessment frameworks (6 dimensions), UN-Habitat City

Prosperity Index (6 dimensions), Integrated Approach for City Enhancement (8 dimensions), LEED for Cities and Communities v. 4.1. (9 dimensions), ISO/DIS 37123 Sustainable cities and communities – Indicators for resilient cities (18 dimensions) and ISO 37120:2018 Sustainable cities and communities – Indicators for city services and quality of life (19 dimensions). It should be noted that the methods mentioned above can be used to assess the sustainable development of cities in various countries. However, there are also methods that have been developed to assess the level of sustainable development of cities located in individual countries (e.g. the Malaysian Urban Indicator Network, the Chinese Sustainable Urban Index or the Pearls Community used in the United Arab Emirates) or which focus on assessing cities of a given continent (e.g. the European Environmental Agency Urban Metabolism Framework or European Green Leaf).

4.3. Determination of methods and indicators for assessing smart sustainable cities

The comprehensive assessment of smart sustainable city performance should use indicators that measure the efficiency of deployment of various smart solutions as well as indicators that measure the contribution towards the environmental, economic and social sustainability.

To the best of our knowledge, there is a lack of commonly agreed comprehensive method that can be used to complex and integrated assessment of smart sustainable city. In relation to this, Monfaredzadeh and Berardi (2015) identified and compared systems for assessing the smartness and sustainability of a city, including 144 sustainable indicators and 143 smart indicators. Their analysis indicated the conflicts and dichotomies that exist in approaching different targets when achieving one goal can make it hard to reach another one. However, the comparison of the different rating systems revealed the strength of the concepts for which they were basically defined. In addition, they recognized the need for multidimensional assessments focused on the complexity of urban issues. Ahvenniemi et al. (2017) analyzed 16 sets of city assessment frameworks (8 related to smart city and 8 related to urban sustainability assessment frameworks) comprising 958 indicators altogether by dividing the indicators under 3 impact categories (i.e. environmental sustainability, economic sustainability, social sustainability) and 10 sectors categories (i.e. 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). They confirmed that there is a large gap between smart city and sustainable city assessment frameworks. In particular, sustainability frameworks contain a large number of indicators measuring environmental sustainability, while smart city frameworks lack environmental indicators and focus on social and economic aspects. Huovilla et al. (2019) developed an interesting taxonomy to evaluate recently published indicator standards for smart and sustainable cities. This taxonomy comprises 5 conceptual urban focuses (i.e. 3 types of urban sustainability: people, planet and prosperity, and 2 types of smartness: hard and soft), 10 city domains (based on categories proposed by Ahvenniemi et al., 2017), and 5 indicator

types (i.e. input, process, output, outcome, impact). Their results clearly discriminate between indicator standards suited for evaluating the implementation of predominantly smart city approaches versus standards more focused on sustainability assessment.

The analysis of existing methods and indicators used for rating smart cities and sustainable cities revealed some approaches that can be used for assessing smart sustainable city. These assessment frameworks include:

- City Protocol – City Protocol Agreement – collaborative innovation framework that fosters city-centric solutions to improve efficient service delivery and overall citizen quality of life. It comprises all the core and supporting ISO 37120:2014 measures with additional indicators of both types (i.e. 53 core indicators CP, 49 core indicators ISO, 37 supporting indicators CP and 57 supporting indicators ISO) (CPA, 2015);
- CITYkeys – holistic performance measurement framework prepared within EU-project developed under the H2020 program to support smart cities in strengthening their strategic planning and monitoring and comparing the implementation of smart city solutions. It comprises 73 city indicators (Bosch et al., 2016);
- Collection Methodology for Key Performance Indicators for Smart Sustainable Cities – framework developed to provide cities with a consistent and standardized method to collect data and measure performance and progress to achieving the Sustainable Development Goals, becoming a smarter city, and becoming a more sustainable city. The framework consists of 54 core indicators and 37 advanced indicators that form the basis for the U4SSC Smart Sustainable City Index (U4SSC 2017);
- ETSI TS 103 463 – Key performance indicators for sustainable digital multiservice cities – the selection of 76 indicators focused on monitoring the evolution of a city towards a smarter city. The selection of indicators for assessing a city was based on an inventory of existing city indicator frameworks, in particular on CITYkeys framework (ETSI, 2017);
- European Smart City ranking – European ranking built on the ‘smart’ combination of endowments and activities of self-decisive, independent and aware citizens, elaborated and published by an international consortium headed by the Vienna University of Technology. It comprises 74 indicators embracing 33 factors describing 6 characteristics (Giffinger, 2007);
- ISO 37120:2018 – Sustainable cities and communities – Indicators for city services and quality of life – standard comprising a set of indicators assessing the performance management of city services, service provisions and quality of life. It considers sustainability as its general principle, and smartness and resilience as guiding concepts in the development of cities. The standard consists of 45 core indicators, 59 supporting indicators and 23 profile indicators (ISO, 2018a);

- ISO 37122:2019 – Sustainable cities and communities – Indicators for smart cities – an indicator standard designed to assist cities in steering and assessing the performance management of city services and all service provisions as well as quality of life. It comprises 85 indicators and considers sustainability as its general principle and "smart city" as a guiding concept in the development of cities (ISO, 2019);
- ISO/DIS 37123 – Sustainable cities and communities — Indicators for resilient cities – a standard defining a set of 73 indicators assessing the resilience in the cities. The condition for achieving sustainable development is skill to maintaining and improving city services and quality of life in the face of shocks and stresses. Therefore, it is supposed that this standard shall be implemented in conjunction with ISO 37120:2018 (ISO, 2018b);
- ITU-T Y.4903/L.1603 – Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals – recommendation which outlines the key performance indicators in the context of smart sustainable cities used to assess the achievement of sustainable development goals. It establishes the criteria, 52 core indicators and 38 additional indicators to evaluate cities' performances and their progress towards becoming smarter and more sustainable (ITU, 2016);
- UN Habitat Agenda Urban Indicators – framework embracing 20 key indicators, 9 check-lists and 13 extensive indicators which measure and monitor performances and trends in attainment of the Habitat Agenda and the Millennium Development Goals adopted by the United Nations (UN, 2004);
- UN Habitat City Prosperity Index – a tool to measure the sustainability of cities which conceptualizes in particular prosperity and identifies its most critical dimensions. It is a composite index based on 62 indicators used to measure how cities create and distribute socio-economic benefits and prosperity (UN, 2016).

The suitability and usefulness of each assessment framework for comprehensive evaluation of smart sustainable city performance was analyzed taking account of the complexity and thoroughness of smartness assessment and sustainability assessment respectively. These methods were assessed according to the Delphi methodology assumptions in three rounds. Firstly, each expert made individual evaluations – 5-level scales were used with the following rates: very low, low, medium, high and very high. Then all evaluations were collected and aggregated and the achieved results were forwarded to each panelist for an eventual verification. Lastly, the final results of the evaluation were determined during the joint meeting and discussion of experts. Table 4 presents the outcomes of comparison of analyzed methods for assessing smart sustainable cities.

Table 4.
The comparison of analyzed methods for assessing smart sustainable cities

Assessment method	Assessment categories	Number of indicators	Smartness assessment		Sustainability assessment	
			Complexity	Thoroughness	Complexity	Thoroughness
City Protocol	• Environment • Infrastructure • Built domain • Functions • Economy • Culture • Information • Citizens • Government	196	Very high	Very high	Very high	Very high
CITYkeys	• People (health, safety, access to (other)services, education, diversity and social cohesion, quality of housing and the built environment) • Planet (energy and mitigation, materials, water and land, climate resilience, pollution and waste, ecosystem) • Prosperity (employment, equity, green economy, economic performance, innovation, attractiveness and competitiveness • Governance (organization, community involvement, multi-level governance)	73	Very high	Very high	Very high	Very high
Collection Methodology for Key Performance Indicators for Smart Sustainable	• Economy (ICT, productivity, infrastructure) • Environment (environment, energy) • Society and culture (education, health and culture, safety, housing and social inclusion)	91	Very high	Very high	High	Very high
ETSI TS 103 463	• People (health, safety, access to (other)services, education, quality of housing and the built environment) • Planet (energy and mitigation, materials, water and land, climate resilience, pollution and waste, ecosystem) • Prosperity (employment, equity, green economy, economic performance, innovation, attractiveness and competitiveness • Governance (organization, community involvement, multi-level governance)	76	High	High	Very high	Very high

Cont. table 4.

European Smart City ranking	• Smart economy (innovative spirit, entrepreneurship, economic image and trademarks, productivity, flexibility of labor market, international embeddedness), • Smart people (level of qualification, affinity to lifelong learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism/open mindedness, participation in public life), • Smart governance (participation in decision-making, public and social services, transparent governance), • Smart mobility (local accessibility, (inter-)national accessibility, availability of ICT infrastructure, sustainable, innovative and safe transport systems), • Smart environment (attractivity of natural conditions, pollution, environmental protection, sustainable resource management) • Smart living (cultural facilities, health conditions, individual safety, housing quality, education facilities, touristic attractivity, social cohesion).	74	Very high	Very high	High	High
ISO 37120:2018	• Economy • Education • Energy • Environment and climate change • Finance • Governance • Health • Housing • Population and social conditions • Recreations • Safety • Solid waste • Sport and culture • Telecommunication • Transportation • Urban/local agriculture and food security • Urban planning • Wastewater • Water	127	Medium	Medium	Very high	Very high

Cont. table 4.

ISO 37122:2019	• Economy • Education • Energy • Environment and climate change • Finance • Governance • Health • Housing • Population and Social Conditions • Recreation • Safety • Solid waste • Sport and culture • Telecommunication • Transportation • Urban/local agriculture and food security • Urban planning • Wastewater • Water	85	Very high	Very high	Medium	Low
ISO/DIS 37123	• Economy • Education • Energy • Environment and climate change • Finance • Governance • Health • Housing • Population and social conditions • Recreations • Safety • Solid waste • Telecommunication • Transportation • Urban/local agriculture and food security • Urban planning • Wastewater • Water	73	Medium	Medium	High	Medium
ITU-T Y.4903/L.1603	• Economy (ICT infrastructure, innovation, employment, trade, productivity, physical infrastructure, public sector) • Environment (air quality, water and sanitation, noise, environmental quality, biodiversity, energy) • Society and culture (education, health, safety, housing, culture, social inclusion)	90	Very high	Very high	Very high	Very high
UN Habitat Agenda urban indicators	• Shelter • Social development and eradication of poverty • Environmental management • Economic development • Governance	42	Low	Low	Very high	Very high
UN Habitat City Prosperity Index (CPI)	• Productivity • Infrastructure development • Quality of life • Equity and social inclusion • Environmental sustainability • Governance and legislation	62	Very high	High	Very high	High

The results of the analysis show that the most comprehensive assessment frameworks that can be used for rating the smart sustainable cities are: City Protocol, CITYkeys and ITU-T Y.4903/L.1603. These metrics are characterized by very high level of complexity and very high thoroughness in relation to both, the possibilities of smartness assessment and opportunities for sustainability assessment.

5. Analysis results of existing gaps in the research on smart and sustainable cities

The analysis of the smart and sustainable city reference literature reveals some important research gaps and issues with potential future contribution. In particular this concerns tensions between smart and sustainable development.

There are growing expectations that smart cities will drive sustainable development. Martin et al. (2018) identified five key tensions between smart city visions and the goals of sustainable urban development. These tensions involve: (1) reinforcing neoliberal economic growth, (2) focusing on more affluent populations, (3) disempowering and marginalizing citizens; (4) neglecting environmental protection, and (5) failing to challenge prevailing consumerist cultures. The tensions mention above may result from the fact that: (1) economic growth is unsustainable, (2) the benefits of digital innovation will be unevenly distributed, (3) digital innovations disempower and marginalize citizens, (4) digitizing urban infrastructure alone does little to protect the environment, and (5) cultures of consumerism are unsustainable. In fact, analysis of relevant case studies revealed that smart city initiatives in practice reinforce the focus on delivering unsustainable forms of economic growth and consumerist cultures, while neglecting social equity and environmental protection (Martin et al., 2018).

Höjer and Wangel (2015) indicate the following challenges for the practical use of the smart sustainable concept: (1) assessment methods need to be developed and used in order to ensure that cities identified as smart sustainable cities are in fact sustainable, (2) mitigating measures will most likely be needed for implementing policies for smart sustainable cities; otherwise, rebound effects may well cancel out the positive effects, (3) the relationship between top–down and bottom–up initiatives needs further exploration, (4) strategies for strengthening city governments' competences are needed, and (5) governance models for smart sustainable city development must be considered.

According to Bibri and Krogstie (2017b) the existing gaps in the research on smart sustainable cities include in particular: (1) the need for applied theoretical grounding for providing an explanation of and a basis for the potentially increased contribution of smart sustainable urban form to the goals of sustainable development, (2) the need for integrated models for spurring the practice of the development and deployment of smart sustainable cities,

(3) the lack of comprehensive framework to be used as a classification system or ranking instrument against which smart sustainable cities can be evaluated in terms of their smart contribution to sustainability, (4) the lack of assessment framework for measuring how smartness enhances sustainability and vice versa, (5) the need for theory for comparing potential models of smart sustainable city according to their contribution to sustainability goals and smartness targets as an integrated approach, (6) the lack of theory building attempts in respect of the integration of sustainable city models and smart city approaches and a paucity of research on conceptual and theoretical models for smart sustainable cities, (7) the need for a holistic and commonly shared model of smart sustainable city given the systematic perspective on and the universal character of sustainability, (8) the lack of conceptual framework for comparing the evolving models of smart sustainable city and planning propositions, (9) the need for applying smart ICT as a constitutive technology to further enhance the contribution of the typologies and design concepts of sustainable urban forms to sustainability, (10) the need for combining the typologies and design concepts of sustainable urban forms with smart methods to evaluate their practicality with regard to their contribution to sustainability, (11) the need for providing normative prescriptions for achieving the status of smart sustainable cities and for developing assessment frameworks for measuring and improving this status, and (12) the lack of analytical studies for testing propositions about what makes a sustainable city smartly more sustainable. It must be noted that sustainable cities remain inadequately scalable in design and flexible in planning without support of smart solutions in response to urban growth, environmental pressures, and changes in socio–economic needs. These cities still focus mainly on infrastructures for urban metabolism, and fall short in considering several urban domains where smart solutions can have substantial contributions in relation to sustainability (Bibri, and Krogstie, 2017b).

It should be noted that there are promising recent research areas concerning holistic approach to the smart and sustainable city concept. In particular, these studies are focused on managerial issues (Jonek-Kowalska et al., 2018; Karwot et al., 2016; Loska, and Paszkowski, 2018).

6. Conclusion

The field of the smart sustainable city is a new phenomenon. This concept has grown substantially since the mid–2010s and has gained recently great attention among researchers, policymakers and practitioners. However, the understanding of the concept is still unclear and inconsistent. Therefore, in order to implement and assess the smart sustainable city, a deeper understanding of this term still needs to be determined.

This article provides a general overview of the smart and sustainable city literature and presents diversity of definitions, dimensions and components of smart city, sustainable city as well as smart sustainable city.

In addition, the smart and sustainable assessment methodologies were indicated and explored. The analysis of existing methods and indicators used for rating smart cities and sustainable cities revealed some interesting approaches that can be used for comprehensive assessment of the smart sustainable city. This concerns, in particular, such assessment frameworks as City Protocol, CITYkeys and ITU-T Y.4903/L.1603. It must be noted that the comparison of measures that can be applied in smart sustainable city evaluation may facilitate the choice of particular methodology depending on the specific city's needs to assess and monitor the efficiency of deployment of various smart solutions and to measure the contribution towards the environmental, economic and social sustainability.

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References

1. Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., and Airaksinen, M. (2017). What are the differences between sustainable and smart cities? *Cities, 60,* 234-245, doi: 10.1016/ j.cities.2016.09.009.
2. Albino, V., Berardi, U., and Dangelico, R.M. (2015). Smart Cities: Definitions, Dimensions, Performance, and Initiatives. *Journal of Urban Technology, 22(1),* 3-21, doi: 10.1080/10630732.2014.942092.
3. Angelidou, M. (2014). Smart city policies: A spatial approach. *Cities, 41(S1),* S3-S11, doi: 10.1016/j.cities.2014.06.007.
4. Baldemir, E., Kaya, F., and Sahin, T.K. (2013). A Management Strategy within Sustainable City Context: Cittaslow. *Procedia - Social and Behavioral Sciences, 99,* 75-84, doi: 10.1016/j.sbspro.2013.10.473.
5. Bibri, S.E. (2018). A foundational framework for smart sustainable city development: Theoretical, disciplinary, and discursive dimensions and their synergies. *Sustainable Cities and Society, 38,* 758-794, doi: 10.1016/j.scs.2017.12.032.

6. Bibri, S.E., and Krogstie, J. (2017a). On the social shaping dimensions of smart sustainable cities: A study in science, technology, and society. *Sustainable Cities and Society, 29,* 219-246, doi: 10.1016/j.scs.2016.11.004.
7. Bibri, S.E., and Krogstie, J. (2017b). Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustainable Cities and Society, 31,* 183-212, doi: 10.1016/j.scs.2017.02.016.
8. Blanco, H., and Mazmanian, D.A. (2015). *Elgar Companion to Sustainable Cities. Strategies, Methods and Outlook*. Cheltenham: Edward Elgar Publishing Limited.
9. Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.M., Airaksinen, M. and Huovila, A. (2016). *Deliverable 1.4 – Smart city KPIs and related methodology – Final.* CITYkeys project.
10. Caragliu, A., Del Bo, C., and Nijkamp, P. (2011). Smart cities in Europe. *Journal of Urban Technology, 18(2),* 65-82, doi: 10.1080/10630732.2011.601117.
11. Castells, M. (2000). Urban sustainability in information age. *City, 4(1)*, 118-122, doi: 10.1080/713656995.
12. City Protocol Agreement (2015). *CPA-PR _002_Anatomy. City Anatomy Indicators. Proposed Recommendation*. TAFT – DICI Indicators.
13. Dhingra, M., and Chattopadhyay, S. (2016). Advancing smartness of traditional settlements-case analysis of Indian and Arab old cities. *International Journal of Sustainable Built Environment, 5*, 549-563, doi: 10.1016/j.ijsbe.2016.08.004.
14. Eger, J.M. (2009). Smart Growth, Smart Cities, and the Crisis at the Pump A Worldwide Phenomenon, *I-WAYS. The Journal of E-Government Policy and Regulation, 32(1),* 47-53, doi: 10.3233/IWA-2009-0164.
15. Estevez, E., Lopes, N., and Janowski, T. (2016). *Smart sustainable cities: Reconnaissance Study*. Ottawa: International Development Research Center.
16. European Telecommunications Standards Institute (2017). *ETSI TS 103 463 – Key performance indicators for sustainable digital multiservice cities. Technical specification*.
17. Ewers, H., and Nijkamp, P. (1990). Urban sustainability. In: P. Nijkamp (Eds), *Urban Sustainability*. Avebury: Gower House.
18. Gardner, G. (2016). Imagining a Sustainable City. In G. Gardner, T. Prugh, and M. Renner (Eds.) *Can a City Be Sustainable?* Washington: Worldwatch Institute.
19. Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanovic, N., and Meijers, E. (2007). *Smart Cities: Ranking of European Medium-Sized Cities*. Vienna: Centre of Regional Science, Vienna University of Technology.
20. Girardet, H. (1999). *Creating sustainable cities.* Dartington: Green Books Ltd. for the Schumacher Society.
21. Global Platform for Sustainable Cities (2018). *Urban Sustainability Framework*. Washington: World Bank.

22. Hall, R.E., Bowerman, B., Braverman, J., Taylor, J., Todosow, H., and Von Wimmersperg, U. (2000). *The vision of a smart city.* Proceedings of the 2nd International Life Extension Technology Workshop, Paris.
23. Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., and Williams, P. (2010). Foundations for smarter cities. *IBM Journal of Research & Development, 2010, 54,* 1-16, doi: 10.1147/JRD.2010.2048257.
24. Hiremath, R.B., Balachandra, P., Kumar, B., Bansode, S.S., and Murali, J. (2013). Indicator-based urban sustainability – A review. *Energy for Sustainable Development, 17*, 555-563, doi: 10.1016/j.esd.2013.08.004.
25. Höjer, M., and Wangel, J. (2015). Smart sustainable cities: definition and challenges. In: L.M. Hilty, and B. Aebischer (Eds.), ICT Innovations for Sustainability. *Advances in Intelligent Systems and Computing, 310,* 333-349.
26. Hollands, R.G. (2008). Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? *City, 12(3),* 303-320, doi: 10.1080/13604810802479126.
27. Huovila, A, Bosch, P., and Airaksinen, M. (2019). Comparative analysis of standardized indicators for Smart sustainable cities: What indicators and standards to use and when? *Cities, 89,* 141-153, doi: 10.1016/j.cities.2019.01.029.
28. Ibrahim, M., Adams, C., and El-Zaart, A. (2015). Paving the way to smart sustainable cities: transformation models and challenges. *Journal of Information Systems and Technology Management*, *12(3)*, 559-576, doi: 10.4301/S1807-17752015000300004.
29. International Standardization Organization (2018a). *ISO 37120:2018 – Sustainable cities and communities – Indicators for city services and quality of life*. Geneva.
30. International Standardization Organization (2018b). *ISO/DIS 37123 – Sustainable cities and communities – Indicators for resilient cities. Draft version*. Geneva.
31. International Standardization Organization (2019). *ISO 37122:2019 – Sustainable cities and communities – Indicators for smart cities*. Geneva.
32. International Telecommunication Union (2014). *Smart sustainable cities: An analysis of definitions*. ITU-T Focus Group on Smart Sustainable Cities. Technical Report.
33. International Telecommunication Union (2016). *Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals. Recommendation ITU-T Y.4903/L.1603*.
34. Janik, A., and Ryszko, A. (2018). *Scientific landscape of smart city concept: a bibliometric analysis*. Proceedings of the 32nd International Business Information Management Association Conference (IBIMA), Seville, 6254-6266.
35. Jarrar, O.M., and Al-Zoabi A.Y. (2008). The applicability of sustainable city paradigm to the city of Jerusalem: Criteria and indicators of efficiency. *Building and Environment*, *43,* 550-557, doi: 10.1016/j.buildenv.2007.01.025.
36. Jenks, M., Burton, E., and Williams, K. (1996). *The Compact City: A Sustainable Urban Form?* London: E and FN Spon.

37. Jonek-Kowalska, I., Kaźmierczak, J., Kramarz, M., Hilarowicz, A., and Wolny, M. (2018). *Introduction to the research project "Smart City: a holistic approach",* 5th International Multidisciplinary Scientific Conference on Social Sciences and Arts SGEM 2018, SGEM2018 Conference Proceedings, 5(2), pp. 101-112.
38. Karwot, J., Kaźmierczak, J., Wyczółkowski, R., Paszkowski, W., and Przystałka, P. (2016). *"Smart water in smart city": a case study*. 16th International Multidisciplinary Scientific GeoConference SGEM 2016. SGEM 2016 Conference proceedings 3(1), Albena, Bulgaria, 851-858.
39. Kourtit, K., and Nijkamp, P. (2012). Smart Cities in the Innovation Age. *Innovation: The European Journal of Social Science Research, 25(2),* 93-95, doi: 10.1080/13511610.2012.660331.
40. Kramers, A., Höjer, M., Lövehagen, N., and Wangel, J. (2014). Smart sustainable cities: Exploring ICT solutions for reduced energy use in cities. *Environmental Modelling & Software, 56,* 52-62, doi: 10.1016/j.envsoft.2013.12.019.
41. Lazaroiu, G.C., and Roscia, M. (2012). Definition methodology for the smart cities model. *Energy, 47,* 326-332, doi: 10.1016/j.energy.2012.09.028.
42. Lombardi, P., Giordano, S., Farouh, H., and Yousef, W. (2012). Modelling the Smart City Performance. *Innovation: The European Journal of Social Science Research, 25(2),* 137-149, doi: 10.1080/13511610.2012.660325.
43. Loska, A., and Paszkowski, W. (2018). SmartMaintenance – The Concept of Supporting the Exploitation Decision-Making Process in the Selected Technical Network System. Intelligent Systems in Production Engineering and Maintenance (ISPEM 2017). *Advances in Intelligent Systems and Computing, 637*, 64-73.
44. Martin, Ch.J., Evans, J., and Karvonen A. (2018). Smart and sustainable? Five tensions in the visions and practices of the smart-sustainable city in Europe and North America. *Technological Forecasting and Social Change, 133*, 269-278, doi: 10.1016/j.techfore.2018.01.005.
45. Meijer, A., and Bolivar, M.P.R. (2016). Governing the smart city: a review of the literature on smart urban governance. *International Review of Administrative Sciences, 82(2),* 392-408, doi: 10.1177/0020852314564308.
46. Molnar, D., Morgan, A.J., and Bell, D.V.J. (2001). *Defining sustainability, sustainable development and sustainable communities. Working paper*. Sustainable Toronto Project. Toronto: University of Toronto.
47. Monfaredzadeh, T., and 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, doi: 10.1080/2093761X.2015.1057875.
48. Nam, T., and Pardo, T.A. (2011). *Conceptualizing smart city with dimensions of technology, people, and institutions*. Proceedings of 12th Annual International Digital Government

Research Conference: Digital Government Innovation in Challenging Times, ACM, New York, 282-291.
49. Rios, P. (2008). *Creating "the smart city"*. Detroit: University of Detroit Mercy.
50. U4SSC (2017). *Collection Methodology for Key Performance Indicators for Smart Sustainable Cities*. Geneva: United for Smart Sustainable Cities.
51. United Nations (2004). *Urban indicators guidelines. Monitoring the habitat agenda and the millennium development goal*. United Nations Human Settlements Programme.
52. United Nations (2013). *World Economic and Social Survey 2013. Sustainable Development Challenges.* E/2013/50/Rev.1. New York: Department of Economic and Social Affairs.
53. United Nations (2016). *Measurement of city prosperity. Methodology and Metadata*. United Nations Human Settlements Programme.
54. United Nations (2019). *World Urbanization Prospects: The 2018 Revision* (ST/ESA/SER.A/420). New York: Department of Economic and Social Affairs, Population Division.
55. Wang, M.-H., Ho, Y.-S., and Fu, H-Z. (2019). Global performance and development on sustainable city based on natural science and social science research: A bibliometric analysis. *Science of the Total Environment, 666*, 1245-1254, doi: 10.1016/j.scitotenv. 2019.02.139
56. WCED (1987). *Our Common Future*. *The World Commission on Environment and Development*. Oxford: Oxford University Press.