Indicators of Sustainable Development and the Urban Sustainability

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ABSTRACT **One of the main challenges for sustainable development is to define a measurement system that would present a current state of the process and direct future actions. The response to this challenge has been provided through the indicators of sustainable development that are promoted by various organisations. This paper starts with a discussion regarding the justification for the need for indicators of sustainable development. Furthermore, the paper illustrates the evolution of various sets of globally applicable indicators, and gives an overview of some particular (composite) indicators of sustainable development. Subsequently, the paper discusses a capital-based approach to the definition of indicators, and considers the interrelations between the economic, environmental, and social spheres of sustainable development. In the last section, different well-known indicators of urban sustainability are presented and compared in the context of the chosen criteria. Finally, an overview of the current most relevant indicators of sustainable development is given, followed by a discussion regarding the further development and application of indicators.**

KEYWORDS urban sustainability, sustainable development, indicators, criteria, challenges

1 Introduction

Sustainable development has been taken as the main determinant and principle of general future development, but it could also be said that it represents an indicator of the progress of society. One of the most important steps in making a successful platform for the action in the sphere of sustainable development is the definition of indicators (e.g. United Nations, 2007; Dalal-Clayton, 1993; Hart, 2002).

The indicators are a compass on the road to sustainability (Spangenberg & Bonniot, 1998). They "help incorporate physical and social science knowledge into decision-making", (United Nations, 2007, p. 3), and are used to assess and present the state of reached development, to measure success in previously applied actions and plans, and to form a basis for (corrective) future measures; as such, the indicators also represent a means of disseminating the level of achieved sustainable development to the public (Neumayer, 2003a; Dalal-Clayton, 1993; Spangenberg & Bonniot, 1998; McKenzie, 2004). The ultimate aim of the application of indicators is to optimise current problems of sustainable development (Minken, 1999) and to formulate future goals.

Concerning the significance of the indicators, this paper aims to explore and present their development from first proposals to the current challenges, by differentiating between the general sets of indicators and the indicators that are intended for a specific domain of sustainable development, and by pointing to the relevance of a capital-based approach in the definition of indicators. To demonstrate the formulation of the indicators intended for a particular social environment, the paper focuses on urban areas, that is, on the presentation and comparison of different indicators and criteria for the assessment of urban sustainability. At the very end, the paper provides an overview of the most current relevant indicators of sustainable development, derived on the basis of a comparison of different studied global frameworks.

2 Development of Indicators of Sustainable Development

2.1 General Indicators Sets

In the action plan *Agenda 21*, representing the outcome of The United Nations Conference on Environment and Development organised in Rio de Janeiro in 1992, a call went out to the countries and the "international, governmental, and non-governmental organisations to develop indicators of sustainable development that can provide a solid basis for decision making at all levels" (United Nations, 2007, p. 5). Following the joint recognition of the need for indicators, an initial set of 134 indicators of the UN Commission on Sustainable Development (CSD indicators) was developed, classified into four main groups (social, economic, environmental, and institutional indicators),

and published in the so-called *blue book* (United Nations, 1996), the pioneering global platform that aimed to cover sustainability in its broad sense and to serve as a reference for the development of national indicators of sustainable development (van de Kerk & Manuel, 2010). In the period from 1996 to 1999, the first CSD indicators were tested in 22 countries. From 1999 to 2001, they were evaluated and revised, which subsequently resulted in the publication of the new edition of the *blue book* containing the reduced set of 58 indicators. The last version of the CSD indicators set was issued in 2007; it contains 50 basic indicators that are part of a larger set of 96 indicators of sustainable development, and all of the main themes that were adopted in 2001 were kept (Table 2.1). In this revised set, the is no longer a division of indicators into social, economic, ecological, and institutional categories, which emphasises the importance of the integration of sustainability pillars (United Nations, 2007).

In line with the United Nations Conference on Environment and Development, the Eurostat and the UN Commission on Sustainable Development (UNCSD) established the collaboration and, in 1997, published the European Union (EU) Sustainable Development Indicator (SDI) compilations. The main aim of the SDI, as defined by the EU Sustainable Development Strategy (SDS), is to improve the general wellbeing that would have an impact on improving the quality of life for present and future generations. The development of the EU indicators was guided by the goal of monitoring the progress regarding the challenges of sustainable development, and their scope included ten thematic sections that covered economic, social, environmental, global, and institutional issues. The latest version of these indicators is based on the document *Transformation of Our World: A Sustainable Development Agenda 2030* (United Nations, 2015) in which the objectives of the post-2015 development were processed. The newly-formed set of indicators is used to measure progress towards the Sustainable Development Goals (SDGs), which count 169 items and aim to stimulate action in the areas that are crucial for the planet and humanity over the next 15 years. They are foreseen as a universal set that will help the world to move towards sustainable development by putting the emphasis on poverty reduction, problems of inequality, and climate change issues (United Nations, 2015).

Another general set of indicators was proposed by the Organisation for Economic Co-operation and Development (OECD) in 2001. Their goal was to measure maintenance of current assets as well as the fulfilment of current needs. Although this set had its limitations because it was not designed to give a broader picture of social-ecological-environmental relations but was more focused on current trends and selected issues, it was easily understandable (Stevens, 2005). The subsequent development of the OECD indicators aimed to "assist decision-makers at all levels to adopt sound national sustainable development policies" (van de Kerk & Manuel, 2010, p. 23). The OECD updates its set of sustainable development indicators on annual basis. The latest outcome of the update – Green Growth Indicators – includes five groups of indicators that are: socioeconomic context and characteristics of

growth; environmental and reduced productivity of economy; natural asset base; environmental dimension of quality of life; and economic opportunities and policy responses (OECD, 2017). The OECD list of indicators is flexible and can be modified according to the needs of a specific country or the availability of new data.

INDICATORS SET / YEAR OF RELEASE / ORGANISATION	GOAL	SCOPE
CSD set / 1996 / UN Commission on Sustainable Development	To measure progress towards sustainable development	– Social – Economic – Environmental – Institutional
CSD set / 2007 / UN Commission on Sustainable Development	To measure sustainable development in its entirety, and by taking into account its multi-dimensional and integrated nature	– Poverty – Governance – Health – Education – Demographics – Natural hazards – Atmosphere – Land – Oceans, seas and coasts – Freshwater – Biodiversity – Economic development – Natural hazards – Global economic partnership – Consumption and production patterns
EU SDI set / 1997 / EUROSTAT	To monitor progress with regard to the challenges of sustainable development	– Socioeconomic development – Sustainable consumption and production – Social inclusion – Demographic changes – Public health – Climate change and energy – Sustainable transport – Natural resources – Global partnership – Good governance
EU SDG set/ 2015/ EUROSTAT	To monitor progress towards sustainable development goals at local, national, regional and global levels	– No poverty – Zero hunger – Good health and well-being – Quality education – Gender equality – Clean water and sanitation – Affordable and clean energy – Decent work and economic growth – Industry, innovation and infrastructure – Reduced inequalities – Sustainable cities and communities – Responsible consumption and production – Climate action – Life below water – Life on land – Peace, justice and strong institutions – Partnerships for the goals

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INDICATORS SET / YEAR OF RELEASE / ORGANISATION	GOAL	SCOPE
OECD set / 2001 / OECD Statistical Office	To measure maintenance of current assets and the satisfaction of current needs	*Resource indicators:* Are we maintaining our asset base? – Environmental assets (air quality, water resources, energy resources, biodiversity) – Economic assets (produced assets, R&D assets, financial assets) – Human capital (stock of human capital, investment in human capital, depreciation of human capital) *Outcome indicators:* Are we satisfying current needs? – Consumption – Income distribution health – Work status/employment – Education
Green Growth Indicators / 2017 / OECD Statistical Office	To monitor progress towards green growth	– Economic growth, productivity and competitiveness – Labour market, education and income – Carbon and energy productivity – Resource productivity – Multifactor productivity – Natural resource stock – Renewable stock – Non-renewable stock – Biodiversity and ecosystems – Environmental health and risks – Environmental services and amenities – Technology and innovation – Environmental goods and services – International financial flows – Prices and transfers – Regulations and management approaches – Training and skill development

TABLE 2.1 General sets of indicators of sustainable development

2.2 Particular (Composite) Indicators

Besides sets of general indicators, there are many other indicators intended for a specific domain of sustainable development, e.g., Ecological Footprint (EF), Living Planet Index (LPI), Environmental Sustainability Index (ESI), Sustainable Society Index (SSI), Happy Planet Index (HPI), Environmental Performance Index (EPI), Human Development Index (HDI) (Table 2.2), etc.

Following the publishing of the first set of the CSD indicators, William Rees and Mathis Wackernagel (1996) defined the **Ecological Footprint** (EF) with the purpose of indicating and quantifying changes that come with human ecological transformation, i.e. urbanisation (Rees & Wackernagel, 1996; Wackernagel & Yount, 1998), with the ultimate goal being the re-establishment of balance between man and nature. There was also an idea that the EF could become an important tool for developing biophysically-based ecological economics (Moffatt, 2000). But only few years after its emergence, the EF approach was criticised for its insufficient determination, lack of comprehensiveness and transparency (van den Bergh & Verbruggen, 1999), and later for its limitations within the policy context (Wiedmann & Barrett, 2010). Nevertheless, Ecological Footprint remains to this day an effective tool

for measuring how fast people and economies consume resources and generate waste compared to how fast nature can absorb that waste and generate new resources (Global Footprint Network, n.d.).

INDICATOR /YEAR OR RELEASE / ORGANISATION	GOAL	SCOPE
Ecological Footprint (EF) /1996/ Global Footprint Network	To indicate ecological changes caused by human demands	– Cropland – Grazing land – Forest – Fishing ground – Built-up land – Carbon
Living Planet Index (LPI) /1997/ WWF	To measure trends in biodiversity	– Terrestrial – Freshwater – Marine
Environmental Sustainability Index (ESI) /2000/ Columbia University and Yale University	To measure progress in achieving sustainable development	*Environmental Systems* (air quality, biodiversity, land, water quality and water quantity) *Reducing Environmental Stresses* (reducing air pollution, ecosystem stress, population pressure, waste & consumption pressures, water stress, and natural resource management) *Reducing Human Vulnerability* (environmental health, basic human sustenance, and exposure to natural disasters) *Social and Institutional Capacity* (environmental governance, eco-efficiency, private sector responsiveness, and science and technology) *Global Stewardship* (participation in international collaborative efforts, greenhouse gas emissions, and reducing trans boundary environmental pressures)
Environmental Performance Index (EPI) /2006/ Columbia University and Yale University	To show the current situation regarding national environmental protection	– *Environmental health* – Health impacts – Air quality – Water and sanitation – *Ecosystem Vitality* – Climate and Energy – Biodiversity and Habitat – Fisheries – Forests – Agriculture – Water Resources
Happy Planet Index (HPI) /2006/ New Economics Foundation	To measure what matters the most to the planet and human wellbeing	– Life satisfaction – Life expectancy – Inequality of outcomes – Footprint
Human Development Index (HDI) /2010/UN	Measure development of a country	– Life expectance – Education – Decent standard of living

TABLE 2.2 Some well-known indicators of sustainable development

The **Living Planet Index** (LPI) measures the changing state of the world's biodiversity over time (Loh et al., 2005, p. 295). This applicative indicator addresses causes, pressures, states, and benefits of biodiversity. It uses information from the **Living Planet Database** (LPD) that represents the most comprehensive collection of data of all populations that inhabit the planet. The relevance of the LPI is growing in line with the existing declining trend of population types (World Wide Fund for Nature, 2016).

The **Environmental Sustainability Index** (ESI) was presented for the first time in 2000, at the World Economic Forum in Davos, Switzerland. It was developed by researchers from the universities of Yale and Columbia (Siche, Agostinho, Ortega, & Romeiro, 2006) as a measurement tool for achieving environmental sustainability (Socioeconomic Data and Applications Center, n.d.). ESI represents a composite indicator, consisting of 21 separate indicators of environmental sustainability that allow for comparison of a range of issues classified into five categories: state of environmental system, both natural and managed; environmental management efforts on those systems; vulnerability of society, as well as the influence and response to changes in the environment; ability of society to deal with environmental stresses; and the contribution of a country to global stewardship (Esty, Levy, Srebotnjak, & de Sherbinin, 2005, p. 11).

Due to the identified needs for changes that would improve the efficiency of the ESI, the **Environmental Performance Index** (EPI) was developed in 2006 to evaluate the performance of countries in the fields of human health protection and the protection of ecosystems (Yale University, n.d.). ESI 2016 recognises environmental health and the vitality of the ecosystem as variables that are relevant for the development of related specific indicators (Table 2.2). While environmental health is about measuring the protection of human health from harmful environmental effects, the vitality of ecosystems measures ecosystem protection and resource management (Yale University, 2016).

The **Sustainability Society Index** (SSI) integrates human and environmental well-being, and above all, economic prosperity. During the development of the SSI, economic well-being was considered as a condition for achieving human and general environmental well-being. The index was released in 2006 by the **Sustainable Society Foundation** (SSF). Since then, SSI has been updated every two years (Sustainable Society Foundation, 2017). According to de Kerk and Manual (2008, p. 239), "the SSI offers a country a practical tool for defining targets on its way to sustainability and for monitoring the progress over time".

Another index presented in 2006, which was equally focused on the sense of well-being, was the **Happy Planet Index** (HPI). This index uses four elements (life satisfaction, life expectancy, inequality of outcomes, and ecological footprint) to best show human effectiveness that varies across countries. The HPI measures environmental efficiency and its positive impact on human life, its length, and happiness. It shows that, even though it is expected that wealthy countries are highly rated on the HPI scale, many other countries with much lower income are far ahead in achieving high life expectancy and well-being (New Economic Foundation, n.d.). Simultaneously, there have been many ambiguities about the HPI, predominantly regarding its understanding. Although it has been widely accepted that the Happy Planet Index measures personal happiness, it actually measures the 'happiness' of the planet. In other words, it deals with the well-being efficiency, i.e. the price of well-being as a function of how many resources are consumed (Heavy Lifting, 2006).

Finally, the **Human Developing Index** (HDI) puts emphasis on people and their abilities, stressing that precisely these factors should be the norm for evaluating the development of a country. The average achievement in the three key dimensions of human efficiency (having a long and healthy life, being knowledgeable, and having a decent standard of living) has been used to present a summary measure of the HDI. The limitations of this index concern simplification and partial caption of the notion of human development, and lack of reflection on inequalities, poverty, human security, empowerment, etc. (United Nations Development Programme, 2016).

3 Capital-Based Approach to Sustainable Development Measurement

The idea of viewing sustainable development from economic, social, and environmental angles came from John Elkington, who defined the so-called 'triple bottom line revolution' (Elkington, 1997). He considered the interconnectedness of these three spheres of human activity and concluded that it was not possible to achieve effective sustainability in a single sphere if it has not been simultaneously forced in other two domains. Many authors based their research on correlations between the three dimensions of sustainability, such that there are studies about socio-ecological relations (e.g., Azar, Holmberg, & Lindgren, 1996; Ostrom, 2009), socioeconomics (e.g., Hannum & Buchmann, 2005; Benhabib & Spiegel, 1994; Riahi, Grubler, & Nakićenović, 2007), as well as relations between the economic sphere and natural wealth (e.g., Constanza & Daly, 1992; Rennings & Wiggering, 1997).

In order to assess sustainability, it is necessary to establish a certain measurement system. This certainly puts the focus on the issue of selecting the values that can actually be measured, and in the most appropriate way. Taking into account the interrelations between the economic, environmental, and social aspects, various methods, systems, and measurement units have been developed, among them the capital-based approach.

In the report *Measuring sustainable development* of the joint UNECE/OECD/Eurostat Working Group on Statistics on Sustainable Development (WGSSD), the promotion of the capital-based approach has been associated with the understanding of "sustainable development as non-declining capita wealth over time" (United Nations, 2008, p. 5). In this document, four types of capital have been taken as the basis of a fundamental measurement of sustainability – economic, natural, human, and social capital.

Due to the complexity in defining economic wealth, economic capital has been divided into financial and produced capital. Financial capital means assets for which there are counterpart liabilities by another institution, such as "currency and other forms of bank deposits, stocks and bonds, derivatives, accounts receivable, pension funds and

insurance reserves" (United Nations, 2008, p. 48), while produced capital implies fixed assets, such as roads, buildings, machinery, harbours, and airports (as tangible ones), and specialised knowledge, original works of artistic value, computer software, etc. as intangible assets (United Nations, 2008).

The earth's natural resources represent the natural capital, both renewable (forests, water, sun, etc.) and non-renewable (land, coal, oil, gas, etc.).

"Human capital means knowledge, skills, competencies and attributes of individuals that contribute to the creation of personal, social and economic well-being" (United Nations, 2008, p. 51). Human capital can be created through the process of consumption, as well as through investment. Social capital, as a relatively new type of capital, puts the focus on "identifying the positive elements of society to be conserved and further developed" (United Nations, 2008, p. 52). Many theoretical approaches to defining social capital are based on the distribution of basic goods, social peace and its maintenance, the protection of society and constitutional goals, and networks and related norms. Although it is hard to determine the exact measure of the contribution of these types of capital in the context of human well-being, no doubt they all aim to improve that state, which is, according to many researchers, the basis of sustainable development. In addition, various approaches to measuring well-being, both individual and collective, have emerged as guidelines for national sustainable development (House of Commons – Environmental Audit Committee, 2012).

In the early stage of the development of indicators, it was very difficult to set the measurement units in which economic, natural, human, and social capitals should be presented. For example, for the capital stocks it seemed that the best option was the monetary measurement, but it was very hard to determine all the positive effects that money has on well-being; even for those contributions that can be registered, their value can be hardly presented in currency. This is especially emphasised for social, human, and natural capital, because their contribution rarely takes place outside the market place. Besides the fact that monetary indicators are an inseparable part of any set of indicators of sustainable development based on capital, physical indicators are seen as necessary when it comes to measuring non-market well-being. Therefore, the UN has made a specific system for economic capital, known as the System of National Accounts (SNA) that represents "a measurement framework for capital-based indicators of sustainable development" (United Nations, 2008. p. 68). Additionally, a set of indicators and a relevant framework has been made for natural capital (the System of Integrated Environment and Economic Accounts). The least attention has been given to social capital, due to its complexity, despite which, however, its indicators are in the regular process of defining and developing. Summa samarium, the capital-based approach requires a measurement framework, both for market place and non-market place, which has led to the basic division of measures into monetary (e.g., real *per capita* economic wealth, real *per capita* genuine economic

savings) and physical ones (e.g., temperature deviations from normal temperatures, greenhouse gas emissions) (United Nations, 2008).

If the measure of the current level of sustainability is important, anticipating future possible outcomes is crucial for sustainable development. In this regard, numerous studies have led to the definition of various indicator sets for all four capital sectors by different organisations such as Eurostat, OECD, CSD. All of these indicators are interconnected, so the well-being benefits cannot be imagined without the decreasing unemployment rates or proper economic planning, and these parameters of development influence the natural capital and vice versa. The indicators are actually seen as main road signs for guiding policy-makers toward sustainable development, in order to enable them to make the integration of four fundamental capitals: environmental, economic, social, and human. Furthermore, "the success of sustainable development programs is determined by their ability to achieve the highest attainable increase in living standards measured against the least possible environmental degradation" (McKenzie, 2004, p. 13).

4 Indicators of Urban Sustainability

Different studies refer to the following domains of key interactions in urban environment: economic, health-related, socio-cultural, environmental (Pakzad, Osmond, & Corkery, 2017; van Kamp, Leidelmeijer, Marsman, & Hollander, 2003), and institutional and governance (Yigitcanlar & Dur, 2010; European Commission, 2015). All these domains mutually depend upon and influence each other, and the complexity of their ties and their effects that extend beyond the city boundaries (especially in the environmental segment), together with the continuous evolution and transformation of the overall urban environment, make the definition of urban sustainability an intricate task.

Urban sustainability relates to "the ability to improve the local quality of life (Human Development Index) whilst remaining below the environmental carrying capacity (environmental footprint)" (Gibberd, 2015, p.49). As a preferred direction of future urban development, sustainable urbanisation actually represents complex system engineering (Zhou, Shen, Song, & Zhang, 2015) that refers to the optimised combination of a broad range of measures aimed at enhancing the quality of environment, economic efficiency, and human well-being (Ali-Toudert & Ji, 2017). Whereas the individual buildings, and infrastructural objects and networks, when observed in isolation from urban systems, act as generators of significant negative environmental impact, their function in systemic considerations is linked to the provision of positive services affecting sustainability, which opens further questions regarding contradictory urban- and building-level sustainability assessments (Kallaos, 2010).

INDICATOR / TOOLKIT	ORGANISATION	GOAL	SCOPE
Urban Ecosystem Europe (2007)	International Council for Local Environmental Initiatives (ICLEI)	– To measure strength and weaknesses of cities in sustainable context	– Local action for health – Natural common goods – Responsible consumption and lifestyle – Planning better mobility and less traffic – Energy and climate change – Local management towards sustainability
Urban Metabolism Framework (2007)	European Environmental Agency	– To model complex urban flows (energy, water, food, people etc.)	– Energy and climate – Water – Waste – Land-use
European Green City Index (2009)	Economist Intelligence Unit	– To measure environmental performance through 30 indicators	– Energy – Buildings – $_{c}$O2 emissions – Transport – Water – Waste and land use – Air quality – Environmental governance
European Green Capital Award (2014)	European Commission	– To guide European environment policy	– Climate change and energy performance – Sustainable urban mobility – Nature, biodiversity and land use – Air quality and noise – Waste and circular economy – Water
City Blueprint (2015)	Waternet Amsterdam	– To define city's challenges and how can they be overcome through sustainability	– Trends and pressures framework – City Blueprint performance framework – Governance capacity framework

TABLE 4.1 An overview of some indicator sets used in Europe

"The biggest advantage of an indicator-based comparative urban sustainability assessment model is the quantifiability of the comparative sustainability levels" (Yigitcanlar & Dur, 2010, p. 323). The role of indicators for urban sustainability is complementary to the role of indicators of overall sustainable development. A literature review reveals that the indicators of urban sustainability and the criteria to which they belong are approached with different methodologies. Munier's method for setting down the urban sustainability criteria is based on the concept of entropy and programming that emphasises finding and measuring of "those aspects of society, economy and technology that make up the sources of pressure on the environment" (Munier, 2011, p. 1021). To select the indicators of urban sustainability, Zhou et al. (2015) proposed the four stages of the responsibility-based method: identifying strategic goals, defining responsive actions, identifying responsibility departments and, in the end, selecting the indicators. According to Cook, Saviolidis, Daviosdottir, Johannsdottir, and Olafsson (2017, p. 463) the optimal methodology for determining indicators has five stages, including the "setting of appropriate policy or trend-based targets given the nation-specific context". At the same time, the researchers emphasise the importance of stakeholders' participation and interaction with them in efficient identification and selection of relevant indicators that would be used later in making

adequate policies and monitoring the progress (Zhou et al., 2015; Tran, 2016; Mascarenhas, Nunes, & Ramos, 2015).

There have been a considerable number of sets of urban sustainability indicators developed worldwide, and some of those used in Europe are presented in Table 4.1. The application of a particular set depends on many factors, especially in terms of identified challenges and set goals.

Urban Ecosystem Europe
Urban Ecosystem Europe is a set of 25 sustainability indicators for integrated assessment of European urban environments within the following main themes: local action for health, natural common goods, responsible consumption and lifestyle, planning better mobility and less traffic, energy and climate change, and local management towards sustainability (European Union, 2014). Some indicators that are included in the assessment system are: particulate matter concentration (PM_{10}), nitrogen dioxide concentration (NO_2), ozone concentration, people exposed to noise pollutions, re-use of rain water, domestic water consumption, waste disposal, low emission public transport, pedestrian areas, public green areas, passengers travelling on public transport, energy consumption of public buildings, etc. By comparing results obtained by using these indicators, every city can define its profile and potential targets for future (Bono, n.d.).

Urban Metabolism Framework
Urban Metabolism Framework is a specific method that treats the urban environment as an ecosystem and intends to foster its orientation towards sustainability. The main idea is to (re)model a city by defining the urban flows of energy, water, waste, people, etc. The method can be used for an analysis of interaction between human activities and the built environment on the one hand, and the natural environment on the other hand (Research Group of the Department of Urbanism – Delft University of Technology, 2007). The Urban Metabolism Framework consists of four main thematic parts, each with a range of corresponding indicators:

- energy (CO_2 intensity of production, transportation, and residential users; carbon footprint, energy efficiency of production, transportation, and residential use; renewable energy production; energy footprint);
- water (territorial water extractions; groundwater levels; water scarcity; water use efficiency; waste water treatment; water quality extraction; water quality release; water footprint);
- waste (waste intensity of production; residential waste intensity; waste recycling; waste incineration; and landfill);
- land-use (soil sealing; land footprint) (Minx, Creutzig, Medinger, Owen, & Baiocchi, 2011).

European Green City Index

European Green City Index measures sustainability level through the following eight domains: energy, buildings, CO_2 emissions, transport, water, waste and land use, air quality, and environmental governance. Water consumption, waste management, environmental governance, and greenhouse gas emissions are just a few of more than 30 indicators from all eight areas that are defined as ranking parameters. This index also emphasises the role of financial funds and wealth in sustainable development strategies, since richer cities have more ambitious policies and goals (Economist Intelligence Unit, 2009). To date, the European Green City Index has been used to quantify and compare the environmental performance of almost every European capital.

European Green Capital Award

European Green Capital Award is recognised as one of the main guiding European policies and action programmes towards sustainability. It emphasises the importance of natural capital, the safety of its citizens, and benefits of moving towards a low-carbon economy. The main principles for achieving these goals are: better implementation of legislation, better information, and investments and protection of the environment and integration of its requirements (European Commission, 2015). The Green Capital Award is given to a city if it fulfils the requirements regarding each of the following 12 environmental indicators that are defined as measurement parameters: climate change – mitigation and adaptation, sustainable urban mobility, sustainable land use, nature and biodiversity, air quality, noise, waste, water, green growth and eco-innovation, energy performance, and governance (European Commission, 2017).

City Blueprint

City Blueprint is diagnostic tool that helps cities to define their sustainable development challenges through seven categories: water quality, solid waste treatment, basic water services, wastewater treatment, infrastructure, climate robustness, and governance. This ranking set includes more than 20 indicators such as water efficiency measurements, climate robust buildings, green space, energy efficiency, drinking water quality, solid waste recovery etc. This indicator also gives climate adaptation options, if they will severely influence the city in the future. Up to now, this diagnostic has been applied to nine cities, of which four are in Europe (Rotterdam, Amsterdam, Hamburg, Istanbul) (van Leeuwen, Frijns, Wezel, & van de Ven, 2012; van Leeuwen & Koop, 2015).

All of the indicator sets presented above aim to assess the sustainability of urban areas by observing them as a whole. They define suitable parameters and explore the values in the interconnection between the built and natural environments. Next to the described methods, a range of assessment models have been developed to assist urban planners and designers, and local decision-makers, e.g., Sustainable Infrastructure, Land-use, Environment and Transport Model (SILENT), Built Environment Sustainability and Quality of Life (BESQoL), LEED for Neighbourhood Development, CASBEE for Urban Development, etc.

5 Discussion and Conclusions

5.1 Current Framework of the Indicators of Sustainable Development

Following the review of different proposed indicators of sustainable development, their development paths and ongoing discussions in the field, the most relevant current indicators of sustainable development are summed up in Fig. 5.1.

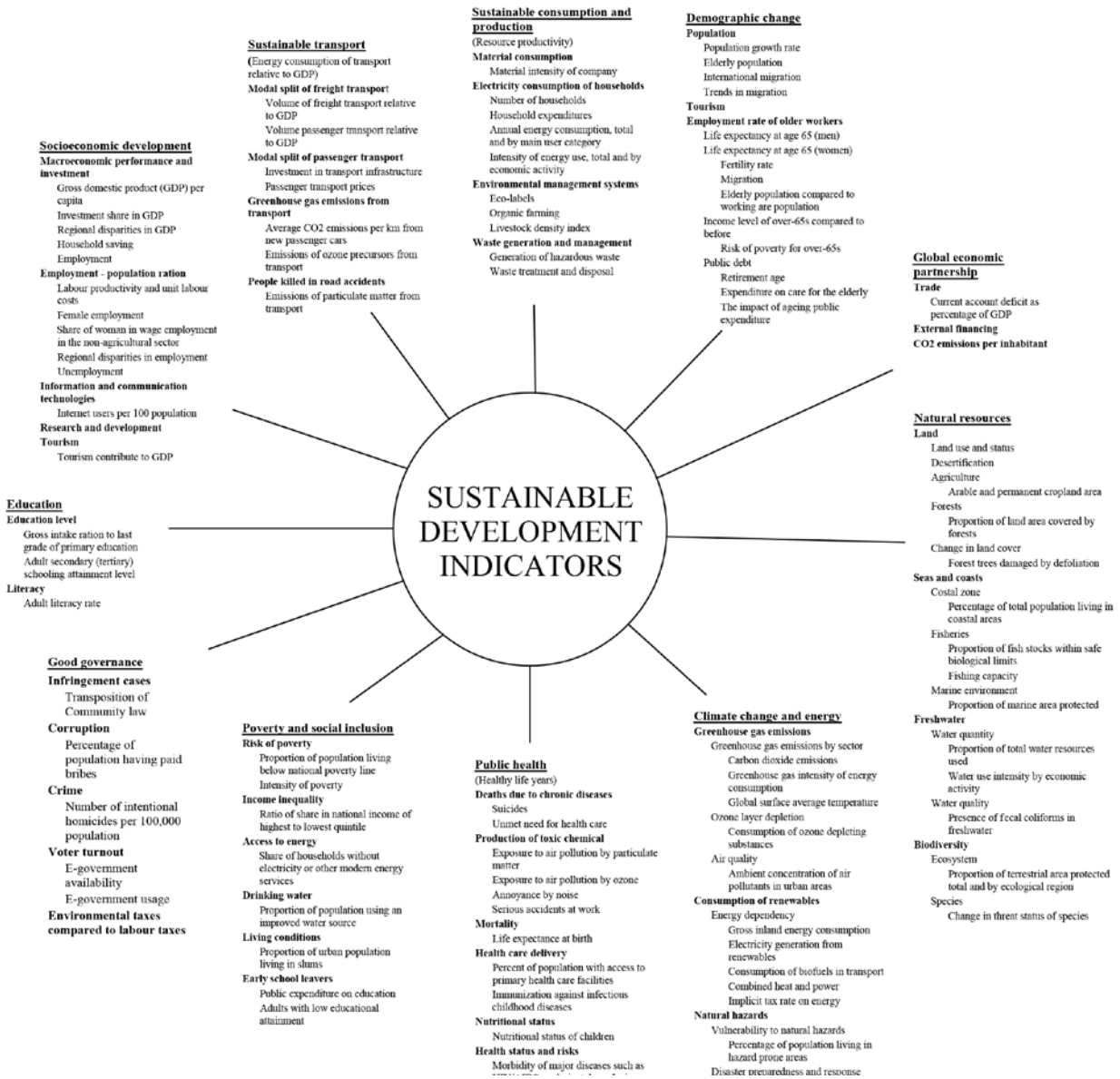

FIG. 5.1 Current framework of the indicators of sustainable development

The presented set consists of 11 groups of indicators: socioeconomic development; poverty and social inclusion; public health; climate change and energy; natural resources; sustainable transport; demographic changes; sustainable consumption and production; good governance; education; and global economic partnership. All of the listed indicators have a particular role in creating a realistic view of the current situation, on the basis of which all the future decisions and actions in relation to sustainable development should be defined. However, at the same time, none of these indicators is independent, and each one influences a number of others to a greater or lesser extent.

Parameters that define **socioeconomic development** such as macro-economic performances and investments, employment, information and communication technologies, research and development, and tourism, must be analysed and adequately measured in order to see possibilities for a given society's future sustainable progress. It is also important to record all of the weaknesses that aggravate the development of society, and to eliminate them if possible. Together with education, socioeconomic development is the driver of general progress. As such, it also affects indicators like **poverty and social inclusion**, which take into account the risk of poverty; income inequality; access to energy; drinking water; living conditions; and early school leavers as relevant indices. When it comes to **public health**, i.e. healthy life years, the deaths due to chronic diseases, production of toxic chemicals, mortality, health care delivery, nutritional status, and health status and risks are seen as the most appropriate measurable values. **Climate change and energy**, as one of the main challenges for developing indicators, consists of three main parts: greenhouse gas emission; consumption of renewables, and natural hazards, which are further divided into: greenhouse gas emissions by sectors (carbon dioxide and greenhouse gas emissions, global surface average temperature); ozone layer depletion (consumption of ozone depleting substances); air quality (air pollutants concentration in urban areas); energy dependency (gross inland energy consumption, generated electricity from renewables, consumptions of biofuels, combined heat and power, implicit tax rate on energy); and, when it comes to natural hazards, vulnerability (percentage of population living in hazard prone areas), disaster preparedness and response are recognised as their indicators. The indicators for **natural resources** imply land (use and status, desertification, agriculture, forests, changes of the cover), seas and coasts (coastal zone, fisheries, marine environment), freshwater (water quantity and quality), and biodiversity (ecosystem and species). **Sustainable transport** or energy consumption of transport relative to GDP relate to reducing: modal split of freight transport; modal split of passenger transport; greenhouse gas emissions from transport; and people with fatal outcomes in road accidents. **Demographic changes** include population variables, tourism trend and employment rates of older workers, while **sustainable consumption and production**, i.e. resource productivity implies material consumption, electricity consumption of household, environmental management systems, and waste generation and management. Infringement cases, corruption, crime, voter turnout, and environmental taxes compared to labour taxes

belong to the **good governance** group of indicators. **Education** considers education level and literacy. Finally, the **global economic partnership** group consists of trade (current account deficit as a percentage of GDP); external financing; and CO_2 emissions per inhabitant.

5.2 The Challenges of Sustainability Indicators

The definition of an indicator is an intricate task. Any effective indicator must have "the capacity to simplify, quantify, analyse, and communicate otherwise complex and complicated information, and the ability to make particular aspects of a complex situation stand out and thereby reduce the level of uncertainty in the formulation of strategies, decisions or actions" (Warhurst, 2002, p 10). In relation to this, the formulation of indicators of sustainable development was recognised as a challenge for two main reasons – the definition of sustainable development and the lack of a common basis for the establishment of indicators, for which reasons, especially in the early analyses of sustainable development, different indicators were used to assess the same items, which further led to the obtainment of different results and disabled the comparison.

In order to enable a more efficient approach to achieving sustainability and defining the indicators, several principles and recommendations have been defined by the United Nations (2011) such as:

- indicators should be harmonised;
- framework should be developed gradually;
- existing data should be reused;
- the capital approach is essential for making a good indicator set;
- the producer and the consumer are equally important;
- collaboration and communication with stakeholders is crucial;
- indicators should be scientifically based;
- a strict system of rules should be developed; and
- timelines should be objective.

Even though a mutual harmonisation is one of the first principles in the process of defining indicators, it is necessary to emphasise that every set of relevant indicators, as well as the accompanying strategies, action plans, and defence mechanisms, should be accustomed to the regional and local levels in order to gain the best possible results.

Climate change has a major impact on all three spheres of sustainable development - economic, social, and natural (European Union, 2015). As such, it also influences the definition of the indicators of sustainable development, either directly or indirectly. An inability to stop climate change has been reflected in the necessity to formulate both adaptive and mitigation-related measures in all relevant strategies (Milovanović, 2015), by considering the complexity of the climate system and addressing uncertainty in the most effective way (Milovanović, Kurtović-Folić, & Lekić, 2017). There are two main ways of embedding climate change into sustainable development: by targeting climate change mitigation

(energy issues) and by defining the inclusion of climate change manifestations into future sustainable development goals, strategies etc.

In addition to ubiquitous climate change, education is the next challenge to be addressed in order to reduce the negative impact caused by human habits that are incompatible with sustainable development. Particular challenges for defining the indicators in this domain are human resources and the coordination of education-related measures.

In a metaphorical sphere of studying the natural environment, the challenge regarding the definition of indicators emerges due to the lack of strict and clear scientific rules by which the measurement parameters would be created (Neumayer, 2003b).

As is the case for general sustainable development, the definition, selection, and application of the indicators of urban sustainability are all complex. To face current challenges successfully and to enhance the use of the indicators of sustainable development, it is necessary to establish a standardised legal basis, allow open access to standardised and comparable data (Klopp & Petretta, 2017), and address both regional and local variations and specificities regarding sustainable development more profoundly.

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