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Review

The Role of Indicator-Based Sustainability Assessment in Policy and the Decision-Making Process: A Review and Outlook

Didem Dizdaroglu

School of Urban Design and Landscape Architecture, Bilkent University, 06800 Ankara, Turkey; dizdaroglu@bilkent.edu.tr; Tel.: +90-312-290-2602

Academic Editor: Tan Yigitcanlar
Received: 8 May 2017; Accepted: 9 June 2017; Published: 16 June 2017

Abstract: In order to regulate natural processes and control the scale of human activities, sustainability assessment needs to be integrated into urban planning. In this context, indicator-based sustainability assessment tools are fundamental instruments that provide information to support policy and decision-making. Indicators are necessary to monitor the implementation of the policies and provide feedback needed to accomplish the desirable state of sustainable urban development. This paper aims to explore the role of indicator-based sustainability assessment in policy and the decision-making process. Therefore, it reviews the identified sustainable development indicator initiatives and addresses the research gaps in the literature for future improvement of sustainability assessment frameworks. It concludes with a discussion that the major problem in sustainability assessment lies in the gathering of reliable and accessible data.

Keywords: sustainable city; sustainability assessment; indicators; policy-making; decision-making

1. Introduction

Expanding urbanisation is one of the leading problems of rapid population growth today. According to the United Nations' world urbanisation prospects report, 54% of the world's population resided in urban areas in 2014 and this number is expected to reach 66% by 2050 [1]. As a result of this scale and speed of the growth, providing adequate infrastructure and flexibility to support the needs of this growing population has led to the development of new approaches to the concept of 'sustainability'. As one of them, sustainability assessment (SA) is a methodology that aims to: (1) contribute to a better understanding of the sustainability and its contextual interpretation; (2) integrate sustainability issues into decision-making by identifying and assessing sustainability impacts, and; (3) foster sustainable development policies [2]. Since it was established, the use of SA tools has spread rapidly with different interpretations and implementations. Over the past decades, various methodologies were developed to perform SA focusing on different scopes (i.e., four pillars of sustainability) and scales (i.e., local, national, and international) [3].

Today, measurement of sustainability problems via indicators has been widely used by the scientific communities, governments and policy-makers. Indicators serve as a powerful tool in evaluating the impacts of environmental issues and making political decisions for achieving sustainability. Indicator selection is often subjective and the choice of an indicator depends on factors such as whether it is cost-effective, easy to understand, scientifically reliable and internationally comparable [4]. Measurability is one of the basic criteria that needs to be taken into account in the development of an effective indicator framework. In recent years, numerous organisations have developed sustainable development indicator (SDI) frameworks at a wide range of geographical units. However, most of them raise important challenges caused by poor quality data. Moreover, many

studies in the literature point out the potential of this approach as well as emphasise a need for further research to gather reliable and accessible data at different geographical scales [5–14].

Due to the importance of SA for taking actions in an attempt to make cities more sustainable, this paper focuses on the role of indicator-based sustainability assessment in policy and decision-making to provide insights for researchers and practitioners. Firstly, it provides insights for the 'sustainable city' by outlining its main characteristics. Secondly, it describes indicator-based sustainability assessment followed by a review of current progress for SDI initiatives across the world. These initiatives are from many countries including Australia, the USA, Canada, the UK, Netherlands, Switzerland, Italy, Germany, France, Ireland, South Africa, Japan, China, Malaysia and Hong Kong and from intergovernmental organisations (Table 1, for more detailed information, please refer to Appendix A). An extensive review of the literature on sustainability indicator frameworks conducted based upon an international literature review and analysis of "grey" literature such as documents published by international organizations, governmental agencies and research institutions available on the internet. Published, peer-reviewed literature was searched using Scopus and the Web of Science databases, while Google was used to search the grey literature. The following keywords were used for searching the literature: "sustainable development indicators", "urban sustainability indicators", "sustainable development indicator initiatives", "sustainability indicator frameworks", "sustainable community indicators", "sustainability indices/index" and "sustainability rating tools". Furthermore, this paper describes the integration of SDIs into policy and the decision-making process. Finally, it concludes with a summary of findings.

Table 1. Identified SDI initiatives.

Initiative/Developer(s)	Scale						
	International	National	State	City/County	Neighbourhood	Building	Housing
United Nations Commission on Sustainable Development (UNCSD) set of indicators	√						
Organisation for Economic Co-operation and Development (OECD) Better Life Index	√						
OECD Green Growth Indicators	√						
EEA core set of indicators By European Environment Agency	√						
World Health Organization (WHO) Environmental Health indicators	√						
EUROSTAT (The statistical office of the European Union)—Indicators for sustainable development	√						
Human Development Index (HDI) By the United Nations Development Programme (UNDP)	√						
Millennium Development Goals Indicators (MDGs) By the United Nations	√						
World Development Indicators (WDI) By the World Bank	√						
Europe 2020 Indicators By the European Union	√						
FEEM Sustainability Index By ENI Enrico Mattei Foundation	√						
The City Prosperity Index By UN-Habitat	√						
ISO 37120:2014 Standards—Indicators for city services and quality of life By the International Organization for Standardization (ISO)—Sustainable development of communities	√						
The Global Power City Index By Mori Memorial Foundation, Japan	√						
The Networked Society City Index By Ericsson	√						
National Footprint Accounts 2014 By the Global Footprint Network	√	√					

Table 1. *Cont.*

Initiative/Developer(s)	Scale						
	International	National	State	City/County	Neighbourhood	Building	Housing
Environmental Sustainability Index By Yale Centre for Environmental Law and Policy and Centre for International Earth Science Information Network of Columbia University	√	√					
Environmental Performance Index By Yale Centre for Environmental Law and Policy and Centre for International Earth Science Information Network of Columbia University	√	√					
The ARCADIS Sustainable Cities Index By London Economic Research Institute Centre for Economics and Business Research (CEBR)	√	√					
The Netherlands: Sustainability Monitor		√					
Well-being in the Netherlands: Statistics Netherland's Measuring Sustainable Development and Societal Progress By Statistics Netherlands		√					
Switzerland: sustainable development indicator system MONET By the Swiss Statistics		√					
Measures of Australia's Progress By Australian Bureau of Statistics		√					
UK government sustainable development indicators By the Office for National Statistics (ONS)		√					
BES (Benessere Equoe Sostenible)—Measuring and Assessing Progress of Italian Society By the Italian National Institute of Statistics (Istat) and the Italian National Council for Economics and Labour (CNEL)		√					
Measuring Ireland's Progress By Central Statistics Office, Ireland		√					
Quality of Life Reporting System By the Federation of Canadian Municipalities		√					
China Urban Sustainability Index By Urban China Initiative		√					
SustainLane U.S. City Rankings		√					
Virginia Performs, USA			√				
Community Indicator Projects in the USA (Baltimore Neighbourhood Indicators Alliance, Boston Indicators Project, Puget Sound Dashboard of Ecosystem Indicators, Sustainable Seattle etc.)				√			
Community Indicator Projects in Australia (City of Sydney indicator framework, Community Indicators Victoria, Community Indicators Queensland, Indicators of Regional Development in Western Australia)			√	√			
Community Indicator Projects in Canada (Sustainable Calgary State of the City report, Alberta's Genuine Progress Indicators)			√	√			
The Glasgow Indicators Project By Glasgow Centre for Population Health				√			
London's Quality of Life Indicators By Greater London Authority				√			
STAR (Sustainability Tools for Assessment and Rating) Community Index By ICLEI—Local Governments for Sustainability, in collaboration with the U.S. Green Building Council, the Centre for American Progress and the National League of Cities				√			
CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) By the Sustainable Building Consortium, Japan				√	√	√	√
SITES (Sustainable Sites Initiative) By the Green Business Certification Inc.					√		
BREEAM (Building Research Establishment Environmental Assessment Method) The Code for Sustainable Homes By the Building Research Establishment, UK					√	√	√
LEED (Leadership in Energy and Environmental Design) By the U.S. Green Building Council					√	√	√

Table 1. *Cont.*

Initiative/Developer(s)	Scale						
	International	National	State	City/County	Neighbourhood	Building	Housing
The Living Building/Community Challenge By International Living Future Institute U.S.					√	√	
Green Star By Australian Green Building Council					√	√	
DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) By the German Sustainable Building Council					√	√	
GBI (Green Building Index) By Pertubuhan Arkitek Malaysia (PAM) and Association of Consulting Engineers (ACEM), Malaysia					√	√	
BASIX (Building Sustainability Index) By NSW Government, Australia						√	
NABERS (National Australian Built Environment Rating System) By the National Department of Environment and Heritage						√	
CEPAS (Comprehensive Environmental Performance Assessment Scheme) By Buildings Department HKSAR Government, Hong Kong						√	
HKBEAM Plus (Hong Kong Building Environmental Assessment Method) By the Hong Kong Green Building Council						√	
Green Globes By ECD Energy and Environment, Canada and USA						√	
HQE (High Environmental Quality) By the Haute Qualité Environnementale Association, France						√	
Green Star SA By the South African Council for Scientific and Industrial Research						√	
BEES (Building for Environmental and Economic Sustainability) By U.S. National Institute of Standards and Technology						√	

2. Characteristics of a Sustainable City

A 'sustainable city' can be defined by integrating four pillars: social development, economic development, environmental management and urban governance [15]. Social development refers to the improvement of the well-being of citizens by achieving social equity which provides full access to public services such as education, health, transport, housing and recreation [16]. Economic development refers to the effective distribution of resources, goods and services to satisfy the needs of all people living in existing and future communities. Environmental management refers to securing the living and physical environment through the sustainable use of resources. Urban governance is an overarching pillar which is required to sustain the integrity of the overall system. Cities that are considered to be sustainable are those which: (1) are socially inclusive in their growth; (2) are environmentally responsible (i.e., have positive or at least minimal adverse impacts on the environment); (3) have a sustainable economy; and; (4) are based on good governance principles (i.e., accountable, responsive, transparent, efficient and effective to the citizens, follow the rules of law, consensus oriented on policies and create opportunities for participation in decision making) [17]. The inter-linkages among the four pillars of sustainable development are evident in cities, which function as integrated systems [18]. In recent years, a large number of communities have started to adopt sustainable development as a goal as evidenced in both constructed projects and planning principles such as: Adelaide Christie Walk Eco-Village Project, Australia; BedZED (Beddington Zero Energy Development) Eco-Village, UK; Malmo Bo01 Ecological District, Sweden; Kawasaki Eco Town Program, Japan; Freiburg Green City, Germany; City of Copenhagen Sustainable City Initiatives, Denmark; City of Portland Sustainable City Principles, Oregon; Melbourne Principles for Sustainable Cities by the United Nations Environment Program, and; Hannover Principles of Design for Sustainability by William McDonough and Michael Braungart. As seen from the examples given above, many different

sets of principles have been developed in order to guide sustainable development of a city. These principles can be summarised under the main headings as follows.

2.1. Sustainable Urban Form and Design

Good urban design contributes to sustainability by: (1) using resources more efficiently; (2) creating a sense of place identity; (3) enhancing diversity of housing forms; (4) creating appropriate residential densities; (5) developing a diverse range of public and semi-private spaces, and; (6) providing spaces for a diverse range of green, locally oriented business. In these ways, urban design and land use strategies work together to create a sustainable city [19–23]. According to Wheeler [24], sustainability can be achieved through five urban form typologies as shown in Table 2.

Table 2. Urban form typologies.

Typology	Benefits
Compact urban form	Limits suburban sprawl by providing more efficient use of land than in conventional suburbia.
Contiguous urban form	Implies that new urban development occurs adjacent to existing urban area.
Connected urban form	Features good street, path and visual connections and is also legible and easy for people to find their way.
Diverse urban form	Contains mixed land use, different typologies and prices/rents.
Ecological urban form	Integrates features of the natural landscape into the form of the city that protects local ecosystems.

2.2. Sustainable Transportation

The goals of sustainable transportation can be summarised as shown in Table 3 [25–29]. Additionally, sustainable logistics improve the environmental performance of urban freight transport systems for creating more liveable cities [30]. As stated by Nathanail et al. [31], some of sustainable logistics include: (1) Restriction/Low emission/Light or low traffic zones; (2) Promotion of green freight transport modes, such as electric vans, bicycles and tricycles for the last mile delivery of goods; (3) Promotion of alternative modes of goods transport such as rail and inland waterways where applicable; (4) Congestion mitigation, incorporating concepts such as the multi-user lanes, and; (5) Use of information systems for enforcement.

Table 3. The goals of sustainable transportation.

Goal	Benefits
Safety	Provide a safe transportation system for users and the general public.
Basic accessibility	Provide a transportation system that offers accessibility that allows people to fulfill at least their basic needs.
Equity/equal mobility	Provide options that allow affordable and equitable transportation opportunities for all sections of society.
System efficiency	Ensure the transportation system's functionality and efficiency are maintained and enhanced.
Security	Ensure the transportation system is secure from, ready for, and resilient to threats from all hazards.
Prosperity	Ensure the transportation system's development and operation support economic development and prosperity.
Economic viability	Ensure the economic feasibility of transportation investments over time.
Ecosystems	Protect and enhance environmental and ecological systems while developing and operating transportation systems.
Waste generation	Reduce waste generated by transportation-related activities.
Resource consumption	Reduce the use of non-renewable resources and promote the use of renewable replacements.
Emissions and air quality	Reduce transportation-related emissions of air pollutants and greenhouse gases.

2.3. Environmental Protection and Restoration

One of the principles of sustainable development is to protect and restore the existing species, habitats and ecosystems by creating ecologically valuable green spaces, designing green buildings and architecture. Green infrastructure is a valuable planning tool for protecting biodiversity, ecosystem functioning and services, promoting societal well-being and supporting green economy, sustainable land and water management. The objectives of green infrastructure are outlined in Table 4 [32–37].

Table 4. The objectives of green infrastructure.

Objectives
To enhance, conserve and restore biodiversity by inter alia increasing spatial and functional connectivity between natural and semi-natural areas and improving landscape permeability and mitigating fragmentation.
To maintain, strengthen, and, where adequate, to restore the good functioning of ecosystems in order to ensure the delivery of multiple ecosystem and cultural services.
To acknowledge the economic value of ecosystem services and to increase the value itself, by strengthening their functionality.
To enhance the societal and cultural link with nature and biodiversity, to acknowledge and increase the economic value of ecosystem services and to create incentives for local stakeholders and communities to deliver them.
To minimise urban sprawl and its negative effects on biodiversity, ecosystem services and human living conditions.
To mitigate and adapt to climate change, to increase resilience and reduce the vulnerability to natural disaster risks—floods, water scarcity and droughts, coastal erosion, forest fires, mudslides and avalanches—as well as urban heat islands.
To make best use of the limited land resources.
To contribute to a healthy living, better places to live, providing services to open spaces and recreation opportunities, increasing urban-rural connections, contributing to sustainable transport systems and strengthening the sense of community.

2.4. Renewable Energy and Waste Management

A sustainable city should be able to power itself by managing and using land efficiently through renewable resources of energy. Table 5 presents an overview of the renewable technologies and their applications. Additionally, waste management practices such as landfill, incineration, biological treatment, zero waste, recycling-orientated eco-industrial parks, environmental taxes, law and policies are necessary for the achievement of sustainability [38–43].

Table 5. The renewable technologies and their applications.

Technology	Application
Wind (grid-connected, stand-alone turbines, wind pumps)	Supplementing mains supply. Power for low to medium electric power needs. Occasionally mechanical power for agriculture purposes.
PV (solar electric, grid-connected, stand-alone, pumps)	Supplementing mains supply. Power for low electric power needs. Pumping water (for agriculture and drinking).
Solar thermal (grid-connected, water heater, cookers, dryers, cooling)	Supplementing mains supply. Heating water. Cooking. Drying crops.
Bioenergy	Supplementing mains supply. Cooking and lighting, motive power for small industry and electric needs. Transport fuel and mechanical power.
Hydropower	Low-to-medium electric power needs. Process motive power for small industry.
Geothermal	Grid electricity and large-scale heating.
Village-scale	Mini-grids usually hybrid systems (solar-wind, solar-diesel, wind-diesel, etc.). Small-scale residential and commercial electric power needs.

2.5. Social Equity and Environmental Justice

The strategies for creating well-balanced and sustainable communities can be summarised as shown in Table 6 [44–47].

Table 6. Social equity and environmental justice related policy objectives.

Policy	Objectives
Transportation	Provide equitable and accessible transportation services for all residents, regardless of income, age, or ability.
Housing	Provide a variety of affordable and quality smart growth housing choices for people of all income levels and abilities.
Healthy environment	Ensure that all our residents, regardless of income or ethnicity, share the benefits of a healthy environment.
Economic prosperity	Provide education and workforce training opportunities that are targeted to residents from a variety of backgrounds and education levels, with an emphasis on outreach to low income communities.
Public facilities	Locate energy facilities (such as power plants and/or transmission lines), site waste disposal and management facilities in a manner that protects public health and safety so that lower income and minority communities are not disproportionately negatively affected.
Public involvement	Provide the involvement of a wide range of residents, including lower income and minority residents, seniors, tribal government representatives and persons with disabilities into decision-making process.

2.6. Economic Development

Sustainable economy initiatives are defined by Nixon [48] in Table 7.

Table 7. Sustainable economy initiatives.

Initiative	Aim
Cleantech Business Cluster	Encouragement of a cluster of businesses offering green products and services, such as energy, water, and/or resource efficiency; renewable energy; alternative transportation; and pollution/waste prevention and recycling.
Green Business	Improvement of the environmental and financial performance of existing firms.
Sustainable Real Estate Development	Promotion of walkable, mixed-use, mixed-income, transit-oriented real estate development.
Green Investment	Initiation of green investment vehicles to invest in green and clean tech businesses and sustainable real estate developments.
Green Jobs	Launch or strengthening of a system for green job development with green skills training training, career pathways, and green entrepreneurship to provide the workforce needed by green and clean tech businesses.
Green and Cleantech Business Attraction and Retention	Promotion of the city/region as an optimal place for green and clean tech businesses to start-up, locate, expand, and grow over the long term.
Green Underserved Communities	Connection of green and clean tech businesses and sustainable real estate developments led by underserved communities with the appropriate business acceleration services and engagement of low- and moderate-income employees and residents in saving money through ecological efficiency.
Sustainability Community Engagement	Engagement of city/regional residents in understanding sustainability, participating in the process of building a sustainable economy, and making green purchasing decisions.

2.7. Healthy Urban Planning

The guiding principles for planning healthy cities can be summarised as shown in Table 8 [49–52].

Table 8. Healthy urban development checklist.

Aim	Objectives
Healthy Food	Promote access to fresh, nutritious and affordable food Preserve agriculture lands Provide support for local food production
Physical Activity	Encourage incidental physical activity Promote opportunities for walking, cycling and other forms of active transport Promote access to usable and quality public open spaces and recreational facilities
Housing	Encourage housing that supports human and environmental health Encourage dwelling diversity Promote affordable housing Ensure that housing is adaptable and accessible
Transport and physical connectivity	Improve public transport services Reduce car dependency and encourage active transport Encourage infill development and/or integration of new development with existing development
Quality Employment	Improve location of jobs to housing and commuting options Increase access to a range of quality employment opportunities Increase access to appropriate job training
Community Safety	Consider crime prevention and sense of security
Public Open Space	Provide access to green space and natural areas Ensure that public open spaces are safe, healthy, accessible, attractive and easy to maintain Promote quality streetscapes that encourage activity Engender a sense of cultural identity, sense of place and incorporate public art Address the preservation and enhancement of places of natural, historic and cultural significance
Social Infrastructure	Provide access to a range of facilities to attract and support a diverse population Respond to existing (as well as projected) community needs and current gaps in facilities and/or services Provide for early delivery of social infrastructure Promote an integrated approach to social infrastructure planning Maximise efficiencies in social infrastructure planning and provision
Social Cohesion and Connectivity	Provide environments that will encourage social interaction and connection amongst people Promote a sense of community and attachment to place Encourage local involvement in planning and community life Minimise social disadvantage and promote equitable access to resources Avoid community severance, division or dislocation
Environment and Health	Contribute to enhancing air quality Contribute to enhancing water quality, safety and supply Minimise disturbance and health effects associated with noise, odour and light pollution Consider the potential for hazards and address their mitigation

3. Assessing Urban Sustainability Using Indicators

The general categorisation of SA framework is arranged on a time continuum based on if they are retrospective (indicators/indices), prospective (integrated assessment) or both (product-related assessment) [53]. The first category consists of *indicators/indices* that are used to monitor the long-term sustainability trends from a retrospective point of view. They provide information in making short-term projections and relevant decisions for the future. The second category consists of *integrated assessment tools* which investigate policy change or project implementation through developing scenarios. They

are divided into three sub-categories: (1) *Multi-Criteria Analysis* is used in the comparison of policy options, by identifying the effects of these options, their relative performance and the trade-offs to be made; (2) *Cost Benefit Analysis* is used for evaluating public or private investment proposals by weighing the costs of the project against the expected benefits, and; (3) *Impact assessment* is a group of forecasting tools used for improving the basis for policy-making and project approval process. The third category consists of *product-related assessment tools* focusing on the material and energy flows of a product or service from a life cycle perspective. They allow both retrospective and prospective assessments that support decision-making. The most established example is the Life Cycle Assessment, which evaluates resource use, and resulting environmental impacts of a product/service throughout its lifecycle across different scales of the built environment as well as the outputs influence environmental policies and regulations [54–56].

Indicator-based SA is increasingly recognized as an important tool which contributes to the planning process. Indicators are statistics or measures that relate to a condition, change of quality, or change in state of something valued. They are selected to provide information about the functioning of a specific system or a specific purpose to support decision-making and management [57]. They have a potential to be used as a tool in terms of providing a basis for informing planning action and in determining the sustainability of planning outcomes [58]. Selecting relevant indicators is necessary to monitor the implementation of the policies and provide feedbacks needed to accomplish the desirable state of sustainable development. As shown in Table 9, a set of criteria needs to be taken into consideration for the selection of the indicators. Another important criterion is that data needs to be both available, and easily accessible [59–63].

Table 9. Selection criteria of key indicators.

Criterion	Reason
Be valid and meaningful	It should reflect the phenomenon it is intended to measure and is appropriate to the needs of the user.
Be sensitive and specific to the underlying phenomenon	It should respond relatively quickly and noticeably to changes.
Be statistically sound	Indicator measurement needs to be methodologically sound and fit for the purpose, to which it is being applied.
Be intelligible	It should be sufficiently simple to be interpreted in practice.
Allow international comparison	It needs to reflect local policy goals/objectives, but also needs to be consistent with other international indicator programs to allow comparisons across countries.
Be consistent over time	The usefulness of indicators is related directly to the ability to track trends over time.
Be timely	Data needs to be collected and reported regularly and frequently, relative to the phenomena being monitored.
Be linked with policy or emerging issues	It should be selected to reflect the important and emerging issues as closely as possible.

Developing an indicator framework is important in terms of suggesting certain ways to think, organise, measure and act. It provides the users focus, purpose, direction, clarity and attention as well as limitations to what indicators can say and do. There are three basic questions involved in building an indicator framework [28]: (1) *Why is the information needed?*—referring to the intention and application; (2) *What information is needed?*—referring to the specific issues or impacts measured, and: (3) *How is the information to be delivered?*—referring to the framework operation. Each framework provides a different set of indicators to answer these questions. Indicators are designed for different purposes to measure progress towards sustainability. They have their own goals, stakeholders and target groups for use and their own characteristics. The main purposes of indicators are summarised as Pastille Consortium [64]:

(1) *Understanding sustainability*—for the identification of relevant issues, analysis of current states and future trends as well as for education and informing the public; (2) *Supporting decisions*—to provide information for the definition of objectives, goals and the identification of action requirements as well as for benchmarking; (3) *Directing*—decision-making in terms of monitoring and evaluation, assessing performance and guiding/controlling; (4) *Involving stakeholders*—for communication, participation, for the initiation of discussions, awareness rising and community empowerment, and; (5) *Solving conflicts and building consensus*—to clarify a discussion and identify differing and common grounds by establishing a common language.

Sustainable development is a multidimensional concept that requires an amalgamation of indicators that can emphasise the connections between the economy, environment and society. To develop an effective indicator set, there is a four-step process which is proposed by the Australian Bureau of Rural Sciences [65]: (1) *Developing a conceptual framework* which clearly defines what is being evaluated and state the question being addressed. The vision for sustainable development needs to be expressed in the form of an overall objective; (2) *Subdividing the overall objective into successively more specific objectives* until getting down to objectives that can be measured. This step requires consultation involving all stakeholders; (3) *Identifying indicators* that address the operational objectives, and: (4) *Aggregating indicators* at lower levels to form a core set for reporting convenience. The information should remain accessible at any level of detail is required. Indicators provide information by aggregating different and multiple data which can be combined so as to communicate complex phenomena in a simple way [66]. In this context, international institutions, many countries and groups are elaborating sets of indicators for sustainable development assessment and monitoring. These indicator sets aim to support policy-making by informing various stages including: (1) monitoring and assessment of conditions; (2) strategic ex-ante impact assessment of policies; (3) assessment of performance in the relevant policy area, and (4) policy analysis and evaluation [67]. Following section presents a review of indicators of sustainable development.

4. Review of the Sustainable Development Indicator Initiatives

Instead of having a 'one-problem, one-indicator' approach, SDIs bring the economic, social and environmental aspects of society together by emphasising the links between them [68]. As stated by Yigitcanlar et al. [14], with a growing sustainability knowledge base, SDIs are commonly employed in SA models. A large number of indicator-based SA tools are developed to measure sustainability performances of urban localities in order to develop necessary remedies for environmental, social, economic and governance issues. Developing sustainability indicators is a very challenging task. Quantitative measurement of sustainability requires various tiers of information including objectives, assessment criteria, indices, indicators and performance variables/parameters. The objectives define the main goals set by the developers of the tools. Major measurement objectives fall under the headings of four dimensions of sustainable development. Assessment criteria which include indices and indicators, provide principles to establish these objectives to be met. They also provide thresholds, benchmarks or reference levels against which sustainability objectives are measured [69]. Various assessment criteria can be identified by determining on the context and scale of the project. Indicator-based SA is conducted at geographical scales varying from building to parcel, street to neighbourhood, city to region, region to national and national to supra-national scales. Each of these tools provides information at a specific geographical scale; building (super-micro), parcel (micro), neighbourhood/suburb (meso), city/region (macro), supra-national (super-macro) [14].

The first SA framework to guide environmental data and indicator development was the STRESS (STress Response Environmental Statistical System) developed by Statistics Canada in the late 1970s. The STRESS framework was based on ecosystem behaviour distinguishing between pressures on the ecosystem, the state of the ecosystem and the ecosystem response. The PSR (Pressure-State-Response) model implemented by the OECD in the 1980s was derived from this example. This framework was further extended by the European Environment Agency (EEA) as

DPSIR (Driving force-Pressure-State-Impact-Response), which can be widely adapted from regional to global levels to provide a more comprehensive approach in analysing problems. Since then, an increasing number of methodologies and tools were launched around the world to perform SA focusing on different scopes, scales and objectives. The identified SDI initiatives (including developer name, scale, themes and headline indicators) are presented in Appendix A. As seen in the Appendix A, local initiatives (i.e., building/neighbourhood/community) serve to local authorities and planners in capturing urban environmental stress under themes such as: (1) site selection and design; (2) materials and construction; (3) operations and maintenance, and; (4) innovation. Their list of indicators reflects their priorities in relation to specific urban policies and strategies. National initiatives serve national policy-makers in comparing across a variety of city sizes, geographic conditions and economic structures. Their list of indicators includes more general classification such as: (1) education; (2) resource use; (3) environment, and; (4) transportation. They also monitor urban sustainability in both private and public sectors. International initiatives concern with the problems that are critical to global sustainability. They include worldwide set of indicators such as: (1) climate change; (2) biodiversity; (3) health; (4) society; (5) economy, and; (6) governance.

In parallel with the increasing popularity of SDIs, some drawbacks have been reported in the literature in terms of the selection and development of indicator sets. As stated by Mayer [6], data unavailability for the majority of aggregated indicators area common weakness of all indices; hence, many of the sustainability indicator indices are not capable of measuring all dimensions of sustainability. Some SA indices demonstrate multiple barriers in terms of data availability during the indicator development process, which raises the issue of missing data treatments. For instance, the Environmental Sustainability Index (ESI) covers 163 countries over 192 United Nations recognized countries due to a lack of adequate data to measure some indicators [70]. After more than 15 years of work, in the last iteration of 2014 Environmental Performance Index (EPI), global data are still lacking on a number of indicators including: toxic chemical exposures; heavy metals (lead, cadmium and mercury); municipal and toxic waste management; nuclear safety; pesticide safety; wetland loss; species loss; freshwater ecosystems health; water quality (sedimentation, organic and industrial pollutants); recycling; agricultural soil quality and erosion; desertification; comprehensive greenhouse gas emissions, and; climate adaptation. Although the data for many of these indicators exist on the regional, sub-national and local scales, insufficient coverage for every country at a global scale excludes their consideration in the EPI [71]. As another example, due to lack of comparable data, countries including Marshall Islands, Monaco, Nauru, Korea, San Marino, Somalia, South Sudan and Tuvalu have been omitted in the calculation of Human Development Index (HDI) [72]. For a number of other studies such as the China Urban Sustainability Index, the European Green City Index and the EEA Urban Metabolism Framework, there is little or no consideration of which data is readily available when the indicator set is proposed. The indicators are chosen based on publically available data to make its implementation easier. Two major indices, Ecosystem Well-being Index (EWI) and Human Well-being Index (HWI), are limited by available data as not all indicators (i.e., components including culture, materials and the state of the oceans) are available for all countries [12].

Additionally, several authors have raised a debate on their effectiveness and success in measuring sustainability [73–78]. According to Hák et al. [79], many indicator initiatives are driven by the availability of relevant and reliable data. The limited quantity and quality of data underlying indicators of sustainability leave them open to criticism. As data collection is expensive, many countries struggle providing data to international organisations which results in producing biased and incomplete indicators sets for measuring sustainability. Scientific research and statistical data collection are well-developed in industrialised countries; hence, their concerns and priorities dominate existing indicators. Pires et al. [80] highlights that some countries have a weak record of participatory approaches in the development of SDIs at the local level and very few governmental initiatives to develop their own local indicator system. Mayer [6] confirms that even they seem different; many of them incorporate the same underlying data because of the small number of available

global sustainability datasets. Mori and Christodoulou [81] argues that this relative evaluation and comparison brings along biased assessments, as data only exists for some entities, which also means excluding many nations from evaluation and comparison. Furthermore, there are temporal biases coming from the lack of long term data sets as well as most researches are concentrated on a narrow time frame linked to the present. Developing new data requires 5–10 years and old data sets exclude relevant indicators that monitor newly emergent issues. The impacts of environmental problems have different temporal and spatial characteristics. Many problems that emerged at the local level (e.g., rapid urbanisation, development of industrialisation and modern transportation systems) many years ago have become national and global problems today. For instance, climate change and biodiversity loss are global issues; however their policy responses and strategies are developed at the national level and applied at the local level. In a similar way, it is difficult to analyse the state of environment only at the local level, because the causes of the implemented policies also affect the environment globally. As a result of this multi-scale characteristic of environmental problems, detailed and up-to-date micro-level data is crucial to assess environmental change at larger scales. Dahl [9] reports that there is a need for developing micro-level indicators appropriate to individuals, families or communities which can give positive feedback for their small sustainability efforts and encourage their further actions. Global environmental problems like climate change are in a larger scale that individuals do not see clearly how they contribute to this problem. Even though, they try to make changes in their lifestyle, consumption patterns or resource use, there is little positive feedback to encourage such behaviours. There is a lack of indicators that are capable of evaluating the level of individual actions or commitments. With the development of these indicators, people will easily manage their own behaviour with reference to their individual goals and they will be motivated continue improvements through new policy intervention and incentives. Turcu [11] states that what seems obvious and important to experts at the 'top' of indicator development might seem less important to citizens at its 'bottom'. By including citizens' values and priorities to indicator development, the focus of indicators could shift from 'input' and 'process' to 'outcome' oriented understanding of local sustainability which provides policy-makers with relevant information to assess sustainability.

5. Integrating Sustainable Development Indicators into Policy and the Decision-Making Process

As pointed out by Dahl [9], a well-designed set of indicators, which are linked to sustainability policies adopted by the local government, updated and reported regularly, can provide clear signals on the success or failure of national policy initiatives and actions. They play an instrumental role in decision-making by supporting the aim of getting more efficient policy outcomes if robust, data-driven and value-free evidence is made available for policy-makers, in a simplified and synthesised format. By clarifying issues and reducing scientific uncertainties, they are applied for monitoring and evaluation of progress at different interrelated levels [82]. Michael et al. [83] (p. 492) explains this relationship as: "*at the local level, the indicators are used mainly in the decision-making processes of urban development by local authorities. Through the involvement of various institutions and service agencies at the regional level, they are used to compare information for the project management and regional development programs. At the international level, the indicators are used to finance regional development projects with international resources and for the development of the cities and communities of the third world*".

According to Clark [84], SDIs contribute policy and the decision-making process in five stages: (1) clarifying goals in reference to the problem of concern; (2) describing trends that have had an impact on the problem of concern; (3) identifying particular impacts and their relation to the achievement of goals; (4) analysing conditions and projecting developments, and: (5) evaluating, and selecting alternatives to resolve the problem. From another point of view, Devuyst et al. [85] (p. 257) express that SDIs play an important role in the following action areas as presented in Table 10. Furthermore, Hezri [86] defines a taxonomy of indicator uses in policy and the decision-making process as shown in Table 11.

Table 10. The role of sustainability indicators.

The Role of Sustainability Indicators
Providing a legal, regulatory, and institutional framework.
Making an inventory of the state of environment, development, existing policies and plans.
Adopting flexible and integrative planning approaches that allow the consideration of multiple goals and enable adjustments of changing needs and means.
Monitoring the development process by comparing what has been reviewed to what has been planned.
Cooperating internationally by taking into account both universal principles and differentiated needs and concerns of all countries.
Participating and strengthening the partnership in support of common efforts toward sustainable development.
Reducing the information gap between existing information and availability of data needed to make informed decisions related to environment and development.

Table 11. Taxonomy of indicator use.

Indicator Use	Explanation
Instrumental use	It occurs when there is a direct link or linear relationships between indicators and decision outcomes (use for action). Fluctuations of indicator values provide empirical evidence that will induce corresponding policy and management responses.
Conceptual use	It occurs when indicators sensitise or change a user's understanding of a problem or situation. Over time, conceptual use may subsequently induce decision outcomes.
Tactical use (of information)	It occurs when indicators, or the process of collecting information, are used either as a delaying tactic, as a substitute for action or to deflect criticisms.
Symbolic use	It is the process of gathering indicators to give ritualistic assurances that those who make the decisions hold appropriate attitudes towards decision-making.
Political use	It occurs where the content of indicators becomes ammunition to support a predetermined position of a user. It is about persuading others to a particular view of the problem and ways to solve it for varying reasons of ideology, interest or intellect.

SA is a very complex and broad concept which requires a method to assist planners in gathering, compiling and analysing the extensive data to clarify and support sustainable design and planning strategies. Although many approaches exist, the research on employing assessment methodologies is still in progress. An example of the methodology for indicator-based SA is developed by Walter and Stützel [87]. In the first stage, the indicator set is determined by identifying the specific problems that need to be assessed and then justifying indicators that adequately describe these problems. Second stage involves two steps: (1) a standardisation procedure to make different indicators comparable, and; (2) sustainability valuation procedure through combining indicators into an index. Finally, the last stage includes strategy development through analysis of weaknesses and strengths, testing alternative options, setting targets and revision. A more comprehensive methodology is developed by the International Union for Conservation of Nature and Natural Resources, involves seven stages presented in Table 12 [88].

By looking at these practices, it is necessary to regulate the natural processes and control the scale of human activities; therefore, SA needs to be integrated into urban planning. This integration is important in terms of understanding the physical characteristics of urban settlements by recognising their strengths, weaknesses, opportunities and threats in the planning process. In this context, SA tools are fundamental instruments that can provide information to support policy and decision-making for all four pillars of sustainability. As defined by Newton et al. [89] (p. 8), "*indicators are physical,*

chemical, biological or socio-economic measures that best represent the key elements of a complex ecosystem or environmental issue". They are used to monitor the long-term sustainability trends from a retrospective point of view. The information they provide helps in making short-term projections and relevant decisions for the future [53]. The studies in the literature show that there is a lack of consistent data sources within and between countries and communities. Therefore, the development of SDIs requires further investigation and more micro-level indicators are needed to be developed to work with more detailed data in SA.

Table 12. Stages of indicator-based sustainability assessment (SA).

Stages	Narratives	Measurement	Mapping
1. Determine the purpose of SA	Define the purpose, uses and users of results for the assessment Determine who will participate in the assessment Determine how the assessment will be undertaken	No activity	No activity
2. Define the system and goals	Define the area (the system) to be assessed Formulate a vision of well-being and sustainable development for the people and ecosystem of the area Define goals that encapsulate the vision	No activity	Prepare base maps of the system
3. Identify elements and objectives	Describe elements and an objective for each element, which will be used for measuring sustainability performance	Compile a metadatabase	Identify sources of mapped data for each element
4. Choose indicators and performance criteria	Explain and justify indicators and performance criteria	Define indicators and their performance criteria	No activity
5. Measure and map indicators	Draw attention to main findings	Measure the indicators and calculate their scores	Map the indicators
6. Combine indicators and map an index	Draw attention to main findings	Combine the indicators into an index	Map the index
7. Review results and assess implications	Analyse performance, discuss causes and implications, and propose policies and actions	No activity	No activity, other than using maps for analysis

6. Conclusions

Cities are densely populated, highly modified systems resulting from destruction, alteration and fragmentation of natural systems by human activities. These activities lead to serious environmental problems such as climate change, deforestation, loss of biological diversity and natural disasters [90]. The effect of human activities on natural resources and their services force us to think about how to face these challenges in a sustainable way. As summarised by Capra [91] (p. 99): "*To build a sustainable society for our children and future generations, we need to fundamentally redesign many of our technologies and social institutions so as to bridge the wide gap between human design and the ecologically sustainable systems of nature*". In this regard, a sustainable framework for urban development is seen as crucial to provide social, economic and ecological resilience of urban systems. SA is increasingly being viewed as an important tool to aid in the shift towards sustainable urban development. SA provides many benefits, including: (1) highlight the economic, social, environmental opportunities and constraints; (2) organize the policy and the decision-making process by reducing the complexity of each stage, and; (3) help governments to reach proposed sustainability targets [92,93]. There is a wide variety of SA tools, among them; sustainability indicators serve as a tool that helps policy and decision-makers in improving their actions towards sustainable urban development.

Since the turn of the millennium, the use of SDIs has evolved significantly as a result of need for better knowledge to address environmental issues on various geographical scales and track progress towards sustainable development goals. For example, the Reference Framework for European Sustainable Cities (RFSC) is developed to serve as an indicator 'toolkit' for all European cities and

offers practical support in integrating sustainability principles into local policies and actions. The Sustainable Community Indicator Catalog is developed by the Department of Housing and Urban Development (HUD), the Department of Transportation (DOT) and the Environmental Protection Agency (EPA) to help communities in measuring progress toward their sustainability objectives. As a smart city innovation, City Dashboards (e.g., Dublin, London, Amsterdam, Chicago) consist of a number of performance indicators which display data about city services, transportation, education, culture, environmental conditions (e.g., weather, water levels, pollution, noise) and public safety. There are various other examples around the world at different scales which is examined in the Appendix A. As a limitation it has to be mentioned that there are several more which is not included in this review.

This paper aims to provide a state-of-the-art overview of current progress for SDI initiatives across the world. The presented examples measure all aspects of sustainability at all scales, from the largest (international) to the smallest (building). However, measuring sustainability is difficult due to the fact that many of the sustainability problems are interlinked and affect each another. There will always be a debate over which is the most appropriate set of indicators to use and in which framework to apply. Moreover, spatial scale is important in the use of indicators as their function is dependent on the context in which they are used. SA frameworks need to include a range of indicators which provide information to function under the national and regional planning systems while being effective for local authorities and communities. The conclusion drawn from the analysis of the literature is that the major problem in SA lies in the gathering of reliable and accessible data. This implies availability of micro-level data as a key criterion for providing useful information in the comparison. Further research is required to develop more effective approaches and solutions supporting the measurable and accessible data for the indicator development. At the same time, more detailed data is needed which is capable of performing a comparative assessment via indicators at micro-level so as to aggregate these assessment findings to national and international levels.

Acknowledgments: This work was supported by the Scientific and Technical Research Council of Turkey (TUBITAK) 2219—International Post-Doctoral Research Fellowship Program (Grant Number: 1059B191500492).

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Table A1. List of Identified SDI Initiatives.

Initiative/Developer(s)	Themes/Headline Indicators	References
The United Nations Commission on Sustainable Development (UNCSD) set of indicators By the United Nations	Poverty Governance Health Education Natural hazards Atmosphere Land Oceans, seas and coasts Freshwater Biodiversity Economic development Global economic partnership Consumption and production patterns	https://sustainabledevelopment.un.org
The Organisation for Economic Co-operation and Development (OECD) Better Life Index	Housing Income Jobs Community Education Environment Civic engagement Health Life Satisfaction Safety Work-Life Balance	http://www.oecdbetterlifeindex.org

Table A1. *Cont.*

Initiative/Developer(s)	Themes/Headline Indicators	References
OECD Green Growth Indicators	The socio-economic context and characteristics of growth The environmental and resource productivity of the economy The natural asset base Environmental quality of life Economic opportunities and policy responses	http://www.oecd.org/greengrowth
EEA core set of indicators By European Environment Agency	Air pollution Biodiversity Climate change Energy Transport Water Other thematic indicators: Fisheries, land, soil, waste, household consumption and green economy	http://www.eea.europa.eu
WHO Environmental Health indicators	Socio-demographic context Air pollution Sanitation Shelter Access to safe drinking water Vector-borne disease Solid waste management Hazardous/ toxic substances Food safety Radiation Non-occupational health risks Occupational health risks	http://www.who.int/ceh/en
EUROSTAT (The statistical office of the European Union) Indicators for sustainable development	Socio-economic development Sustainable consumption and production Social inclusion Demographic changes Public health Climate change and energy Sustainable transport Natural resources Global partnership Good governance	http://ec.europa.eu/eurostat
Human Development Index (HDI) By the United Nations Development Programme (UNDP)	Health Education Income/Composition of Resources Inequality Gender Poverty Work, employment and vulnerability Human Security Trade and Financial Flows Mobility and Communication Environmental sustainability Demography	http://hdr.undp.org
Millennium Development Goals Indicators (MDGs) By the United Nations	Eradicate extreme poverty and hunger Achieve universal primary education Promote gender equality and empower women Reduce child mortality Improve maternal health Combat HIV/AIDS, malaria and other diseases Ensure environmental sustainability Develop a global partnership for development	http://mdgs.un.org

Table A1. *Cont.*

Initiative/Developer(s)	Themes/Headline Indicators	References
World Development Indicators (WDI) By the World Bank	Agriculture and Rural Development Aid Effectiveness Climate Change Economy and Growth Education Energy and Mining Environment External Debt Financial Sector Gender Health Infrastructure Poverty Private Sector Public Sector Science and Technology Social Development Social Protection and Labor Trade Urban Development	http://data.worldbank.org
Europe 2020 Indicators By the European Union	Employment rate Research and development (R&D) Climate change and energy Education Poverty and social exclusion Resource efficiency	http://ec.europa.eu/eurostat
FEEM Sustainability Index By ENI Enrico Mattei Foundation	Economy Society Environment	http://www.feemsi.org
The City Prosperity Index By UN-Habitat	Productivity Infrastructure Quality of life Equity and social inclusion Environmental sustainability	http://unhabitat.org
ISO 37120:2014 Standards - Indicators for city services and quality of life By the International Organization for Standardization (ISO)—Sustainable development of communities	Economy Education Energy Environment Finance Fire and Emergency Response Governance Health Recreation Safety Shelter Solid Waste Telecommunication and Innovation Transportation Urban Planning Wastewater Water and Sanitation	http://www.iso.org
The Global Power City Index By Mori Memorial Foundation, Japan	Economy Research and development Cultural interaction Livability Environment Accessibility	http://www.mori-m-foundation.or.jp

Table A1. *Cont.*

Initiative/Developer(s)	Themes/Headline Indicators	References
The Networked Society City Index By Ericsson	ICT Maturity: - Infrastructure - Affordability - Usage Triple Bottom Line - Social - Economy - Environment	http://www.ericsson.com
National Footprint Accounts 2014 By the Global Footprint Network	Includes two measures: - Ecological Footprint: a measure of the demand populations and activities place on the biosphere in a given year, given the prevailing technology and resource management of that year. - Biocapacity: a measure of the amount of biologically productive land and sea area available to provide the ecosystem services that humanity consumes.	http://www.footprintnetwork.org
Environmental Sustainability Index By Yale Centre for Environmental Law and Policy and Centre for International Earth Science Information Network of Columbia University	Environmental Systems Reducing Environmental Stresses Reducing Human Vulnerability Social and Institutional Capacity Global Stewardship	http://www.yale.edu/esi
Environmental Performance Index By Yale Centre for Environmental Law and Policy and Centre for International Earth Science Information Network of Columbia University	Health Impacts Air Quality Water and Sanitation Water Resources Agriculture Forests Fisheries Biodiversity and Habitat Climate and Energy	http://epi.yale.edu
The ARCADIS Sustainable Cities Index By London Economic Research Institute Centre for Economics and Business Research (CEBR)	People Planet Profit	http://www.sustainablecitiesindex.com
The Netherlands: Sustainability Monitor	Quality of life Resources Netherlands in the world	http://www.cbs.nl
Well-being in the Netherlands: Statistics Netherland's Measuring Sustainable Development and Societal Progress By Statistics Netherlands	Wellbeing Consumption and income Health Housing Education Leisure Inequality Physical safety Trust Shared norms and values Institutions Energy reserves Non-energy reserves Land and ecosystems Water Air quality Climate Labour Physical capital Knowledge capital Financial capital	http://www.cbs.nl

Table A1. *Cont.*

Initiative/Developer(s)	Themes/Headline Indicators	References
Switzerland: sustainable development indicator system MONET By the Swiss Statistics	Meeting needs—How well do we live? Fairness—How well are resources distributed? Preservation of resources—What are we leaving behind for our children? Decoupling—How efficiently are we using our natural resources?	http://www.bfs.admin.ch
Measures of Australia's Progress By Australian Bureau of Statistics	Society Economy Environment Governance	http://www.abs.gov.au
UK government sustainable development indicators By the Office for National Statistics (ONS)	Economy Society Environment	https://www.gov.uk
BES (Benessere Equoe Sostenible)—Measuring and Assessing Progress of Italian Society By the Italian National Institute of Statistics (Istat) and the Italian National Council for Economics and Labour (CNEL)	Health Education and training Work and life balance Economic well-being Social relationships Politics and Institutions Security Subjective well-being Landscape and cultural heritage Environment Research and innovation Quality of services	http://www.misuredelbenessere.it
Measuring Ireland's Progress By Central Statistics Office, Ireland	Society - Population - Social cohesion - Crime Economy - Finance - Employment and unemployment - Housing Environment Education Health	http://www.cso.ie
Quality of Life Reporting System By the Federation of Canadian Municipalities	Demographic Background Information (DBI) Affordable, Appropriate Housing (AAH) Civic Engagement (CE) Community and Social Infrastructure (CSI) Education (ED) Employment and Local Economy (ELE) Natural Environment (NE) Personal and Community Health (PCH) Personal Financial Security (PFS) Personal Safety (PS)	http://www.fcm.ca
China Urban Sustainability Index By Urban China Initiative	Social welfare Cleanliness Built environment Economic development Resource utilization	http://www.urbanchinainitiative.org
SustainLane U.S. City Rankings	Air and Water Quality Transportation Built Environment City Programs Green Biz and Economy Natural Disaster Risk Waste Management Water Supply	http://www.vtpi.org

Table A1. *Cont.*

Initiative/Developer(s)	Themes/Headline Indicators		References
Virginia Performs, USA	Economy Education Health and Family Public Safety Natural Resources Transportation Government and Citizens		http://vaperforms.virginia.gov
Community Indicator Projects in the USA	Adams County Community Indicators, Adams County, Illinois Arizona Indicators, Arizona Baltimore Neighbourhood Indicators Alliance, Baltimore, Maryland Boston Indicators Project, Greater Boston Region, Massachusetts Central Texas Sustainability Indicators Project, Austin, Texas City of Minneapolis Sustainability Indicators, Minneapolis, Minnesota City of Vancouver, WA Strategic Indicators, Vancouver, Washington Community Indicators of Vitality, Oregon, Portland Dakota County Community Indicators, Dakota County, Minnesota Florida Scorecard, Florida Georgia Community Indicators, State of Georgia Greater New Orleans Index, Greater New Orleans, Louisiana Greenville Indicators, Greenville County, South Carolina Gulf Coast Community Indicators, Sarasota, Bradenton, Charlotte, DeSoto Counties, Florida Houston Sustainability Indicators, Houston, Texas Jacksonville Quality of Life Indicators, Jacksonville/Duval County, Florida Kewaunee County, Wisconsin Quality of Life Report, 2012, Kewaunee County, Wisconsin Kootenai County Indicators, Kootenai County, Idaho Orange County Community Indicators Project, Orange County, California Puget Sound Dashboard of Ecosystem Indicators, Puget Sound, Seattle, Washington Santa Monica Sustainable City Plan, Santa Monica, California Spartanburg Community Indicators Project, Spartanburg, South Carolina Spokane County Community Indicators Initiative, Spokane County, Washington Sustainable Seattle, Greater Seattle/King County, Washington Sustainable Cleveland 2019, Cleveland, Ohio Sustainable Chattanooga, Tennessee		http://www.communityindicators.net
Community Indicator Projects in Australia	City of Sydney indicator framework Community Indicators Victoria Community Indicators Queensland Indicators of Regional Development in Western Australia	Healthy Safe and Inclusive Communities Dynamic Resilient Local Economies Sustainable Built and Natural Environments Culturally Rich and Vibrant Communities Democratic and Engaged Communities Economic goal—Growing a diversified economy Social goal—Educated, healthy, safe and supportive communities Environmental goal—Valuing and protecting the environment	http://www.cityofsydney.nsw.gov.au http://www.communityindicators.net.au http://www.communityindicatorsqld.org.au http://myweb.westnet.com.au

Table A1. *Cont.*

Initiative/Developer(s)	Themes/Headline Indicators		References
Community Indicator Projects in Canada	Sustainable Calgary State of the City report	Community indicators Economic indicators Education indicators Natural environment indicators Resource use indicators Wellness indicators	https://www.pembina.org
	Alberta's Genuine Progress Indicators	Economic Social Environmental	
The Glasgow Indicators Project By Glasgow Centre for Population Health	Population Economic participation Poverty Health Social capital Environment Transport Education Community Safety Lifestyle Cultural Vitality Mindset		http://www.understandingglasgow.com
London's Quality of Life Indicators By Greater London Authority	Environmental Indicators Social Indicators Economic Indicators		http://data.london.gov.uk
STAR (Sustainability Tools for Assessment and Rating) Community Index By ICLEI—Local Governments for Sustainability, in collaboration with the U.S. Green Building Council, the Centre for American Progress and the National League of Cities	Natural Systems Built Environment Climate and Energy Economy and Jobs Education, Arts and Community Equity and Empowerment Health and Safety Innovation and Process Credits		http://www.starcommunities.org
CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) By the Sustainable Building Consortium, Japan	Building (New Construction) - Environmental quality of building - Environmental load reduction of building Home (Detached House) - Comfortable, Healthy and Safe Indoor Environment - Ensuring a Long Service Life - Creating a Richer Townscape and Ecosystem - Conserving Energy and Water - Using Resources Sparingly and Reducing Waste - Consideration of the Global, Local, and Surrounding Environment Neighbourhood development - Environmental quality of urban development - Environmental load of urban development Cities (Pilot version) - Environment - Society - Economy		http://www.ibec.or.jp/CASBEE
SITES (Sustainable Sites Initiative) By the Green Business Certification Inc.	Site Selection Pre-Design Assessment and Planning Site Design—Water Site Design—Soil and Vegetation Site Design—Materials Selection Site Design—Human Health and Well-Being Construction Operations and Maintenance Monitoring and Innovation		http://www.coconino.az.gov

Table A1. *Cont.*

Initiative/Developer(s)	Themes/Headline Indicators	References
BREEAM (Building Research Establishment Environmental Assessment Method) The Code for Sustainable Homes By the Building Research Establishment, UK	New Construction - Management - Health and Wellbeing - Energy - Transport - Water - Materials - Waste - Land Use and Ecology - Pollution - Innovation Community - Establishing the principle of development - Determining the layout of the development - Designing the details The Code for Sustainable Homes - Energy and Carbon Dioxide Emissions - Water - Materials - Surface Water Run-off - Waste - Pollution - Health and Well-being - Management - Ecology	http://www.breeam.com http://www.planningportal.gov.uk
LEED (Leadership in Energy and Environmental Design) By the U.S. Green Building Council	Homes - Location and Transportation - Sustainable Sites - Water Efficiency - Energy and Atmosphere - Materials and Resources - Indoor Environmental Quality - Innovation Neighbourhood Development - Smart Location and Linkage - Neighbourhood Pattern and Design - Green Infrastructure and Buildings - Innovation and Design Process	http://www.usgbc.org/leed
The Living Building/Community Challenge By International Living Future Institute U.S.	Site Water Energy Health Materials Equity Beauty	http://living-future.org
Green Star By Australian Green Building Council	Design and As Built - Management - Indoor Environment Quality - Energy - Transport - Water - Materials - Land Use and Ecology - Emissions - Innovation Community - Governance - Liveability - Economic Prosperity - Environment - Innovation	https://www.gbca.org.au/green-star
DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) By the German Sustainable Building Council	Environmental Quality Economic Quality Sociocultural and Functional Quality Process Quality Technical Quality Site Quality	http://www.dgnb.de/en

Table A1. *Cont.*

Initiative/Developer(s)	Themes/Headline Indicators	References
GBI (Green Building Index) By Pertubuhan Arkitek Malaysia (PAM) and Association of Consulting Engineers (ACEM), Malaysia	Residential New Construction - Energy Efficiency - Indoor Environment Quality - Sustainable Site Planning and Management - Materials and Resources - Water Efficiency - Innovation Township Rating Tool - Climate, Energy and Water - Environmental and Ecology - Community Planning and Design - Transportation and Connectivity - Building and Resources - Business and Innovation	http://new.greenbuildingindex.org
BASIX (Building Sustainability Index) By NSW Government, Australia	- Energy - Water - Thermal comfort	https://www.basix.nsw.gov.au
NABERS (National Australian Built Environment Rating System) By the National Department of Environment and Heritage	Energy Water Waste Indoor Environment	http://www.nabers.gov.au
CEPAS (Comprehensive Environmental Performance Assessment Scheme) By Buildings DepartmentHKSAR Government, Hong Kong	Indoor Environmental Quality Building Amenities Resources Use Loadings Site Amenities Neighbourhood Amenities Site Impacts Neighbourhood Impacts	http://www.bd.gov.hk/english
HKBEAM Plus (Hong Kong Building Environmental Assessment Method) By the Hong Kong Green Building Council	Existing Buildings - Selective Scheme - Management - Site Aspects - Materials and Waste Aspects - Energy Use - Water Use - Indoor Environmental Quality	https://www.hkgbc.org.hk/eng
Green Globes By ECD Energy and Environment, Canada and USA	Project management Site Energy Water Materials and resources Emissions and other impacts Indoor environment	http://www.greenglobes.com
HQE (High Environmental Quality) By the Haute Qualité Environnementale Association, France	Eco-construction Eco-management Create a healthy and comfortable internal environment Health	http://www.behqe.com
Green Star SA By the South African Council for Scientific and Industrial Research	Existing Building Performance - Management - Indoor environmental quality - Energy - Transport - Water - Materials - Land use and ecology - Emissions - Innovation	https://www.gbcsa.org.za

Table A1. *Cont.*

Initiative/Developer(s)	Themes/Headline Indicators	References
BEES (Building for Environmental and Economic Sustainability) By U.S. National Institute of Standards and Technology	Environmental Performance Score - Global Warming - Acidification - Eutrophication - Fossil Fuel Depletion - Indoor Air Quality - Habitat Alteration - Water Intake - Criteria Air Pollutants - Human Health - Smog - Ozone Depletion - Ecological Toxicity Economic Performance	http://nepis.epa.gov

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