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Proposing an Indicator System for Measuring City Sustainability

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1 ABSTRACT

An increasingly rapidly urbanising world highlights sustainable urban development as an inevitable crucial issue that has recently been at the forefront of numerous scientific inquiries. Measuring city sustainability contributing to the quality of urbanisation is a substantial research field in this area. Meanwhile, a comprehensive functional indicator system, including accurate indicators, is the first point of measuring city sustainability. Hence, this paper aims to propose an indicator system for measuring city sustainability by analysing current research and experiences, including existing frameworks, indicator systems, and case studies. Through a systematic literature review of articles published by Elsevierand MDPI from 2019 onwards, an indicator system has been developed that could be applied for measuring city sustainability according to available and accessible data. It includes the 21 most frequent indicators based on the three main subsystems of economy, society, and environment. Concerning their effects on city sustainability, they were categorised into two properties of benefit and cost regarding the sustainable development of a city. Thus, seven indicators measure the economic dimension, sevenconsider the social dimension, and seven address the environmental dimension. Conducting empirical case studies following the proposed indicator system accompanied by weighting approaches and aggregating methods as another significant issue concerning measuring city sustainability will complement the current path to future further research.

Keywords: Indicator System; Sustainability; Sustainable City; Sustainable Development; Urban Sustainability

2 INTRODUCTION

City sustainability is extremely important because it directly contributes to the quality of urbanisation (Li and Yi, 2020). In an increasingly rapid urbanising world, city sustainability has been the focus of numerous academic studies (Liu et al., 2020). The interest in research on city sustainability as an emergent concept has grown exponentially, and it has been at the front of scientific inquiries in recent years (Xie et al., 2022). We need to understand where we are and where we are going. Thus, searching for sustainable development at the urban level and how cities can approach sustainability is of interest (Tomatis et al., 2022).

The cities require more and more to be transformedto become more sustainable through pursuing a sustainability agenda (Antolín et al., 2020; Hassan and Kotval-K, 2019). Measuring city sustainability by providing the possibility to know cities' status and preparing baselines for decision makers has a notable role in this regard (Zhou et al., 2021).It could provide an important reference for sustainable urban development. However, sustainability is a multi-dimensional system that requires a comprehensive, accurate, and rational index system for evaluation (Gong et al., 2019).Incorporating sustainability into local urban planning depends on measuring city sustainability and developing indicators for it (Hassan and Kotval-K, 2019). Therefore, indicator selection is the first point of measuring city sustainability, and accordingly, the accuracy of the indicator system has a significant effect on the results (Zhou et al., 2021).

While measuring city sustainability performance has become an attractive and popular broad research field, a comprehensive functional indicator system has not been well developed (Yi et al., 2019b).Current studies on sustainable urban systems lack complete analytical frameworks for indicator selection and focus mainly on ecological aspects that depend on the selections of indicators, often challenged by the limitation of available and accessible data (Xie et al., 2022). Despite numerous pieces of literature on city sustainability, it is still a complicated area where multiple indicators and measures already exist regarding different purposes and agendas (Liu et al., 2020).

Hence, this paper aims to propose an indicator system for measuring city sustainability. For this purpose, a systematic literature review has been considered, which is explained in the methodology section. It resulted in identifying and screening the articles published by Elsevier and MDPI from 2019 onwards, following four search keywords for the titles: sustainable city, urban sustainability, sustainable urban development, and city sustainability. Among the identified articles, nine articles were finally selected, and the results section analyses them, focusing on the indicator system for measuring city sustainability.

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3 METHODOLOGY

The systematic literature review was used to focus on recent studies published by Elsevier and MDPI from 2019 onwards. Accordingly, the ScienceDirect and MDPI databases were explored following the title search strategy in the middle of July 2022. Consequently, 84 and 108, 82 and 106, 28 and 35, and 14 and 35 articles were found in Elsevier and MDPI, respectively, by considering four keywords of sustainable city, urban sustainability, sustainable urban development, and city sustainability. Tables 1 and 2 show the details of these articles based on their types and years of publishing.

Search Keyword	Article Type		Year	
sustainable city	research article	74	2019	21
			2020	11
	review article	10	2021	27
			2022	25
	Total		84	
urban sustainability	research article	69	2019	22
			2020	25
	review article	13	2021	23
			2022	12
	Total		82	
sustainable urban development	research article	22	2019	6
			2020	5
	review article	6	2021	5
			2022	12
	Total		28	
city sustainability	research article	13	2019	3
			2020	5
	review article	1	2021	4
			2022	2
	Total		14	

Table 1: Details of the identified recent articles on city sustainability published by Elsevier

Search Keyword	Article Type		Year	
sustainable city	article	102	2019	20
			2020	26
	review	6	2021	39
			2022	23
	Total		108	
urban sustainability	article	95	2019	27
			2020	27
	review	11	2021	36
			2022	16
	Total		106	
sustainable urban development	article	30	2019	7
			2020	9
	review	5	2021	11
			2022	8
	Total		35	
city sustainability	article	34	2019	10
			2020	8
	review	1	2021	11
			2022	6
	Total		35	

Table 2: Details of the identifiedrecent articles on city sustainability published by MDPI

Figure 1 presents the distribution of the city sustainability articles published by Elsevier and MDPI based on years of publishing. Figure 2 also shows them based on the title's search keywords and years of publishing. First, 40 articles were included by reviewing the title and the abstract. Subsequently, in the second-level screening, by reviewing the full content, fifteen and then nine articles were selected for further analysis regarding proposing an indicator system for measuring city sustainability. Fifteen mentioned articles have been presented in the references section.

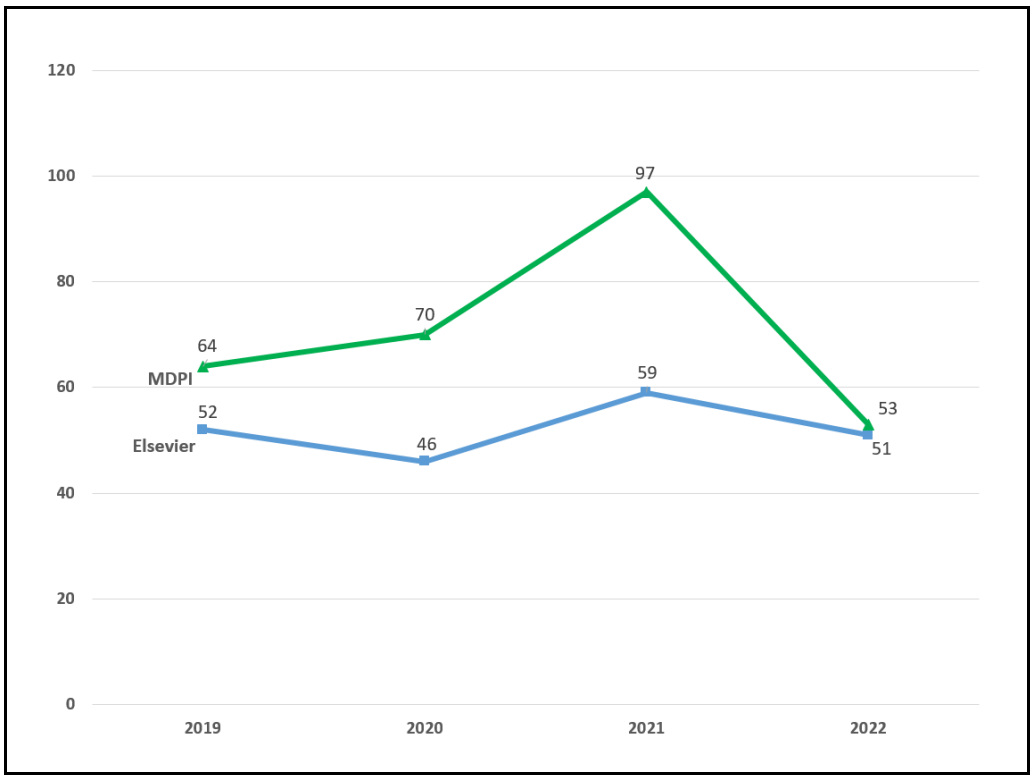

Fig. 1: Distribution of the identified recent articles on city sustainabilitypublished by Elsevier and MDPI based on years of publishing

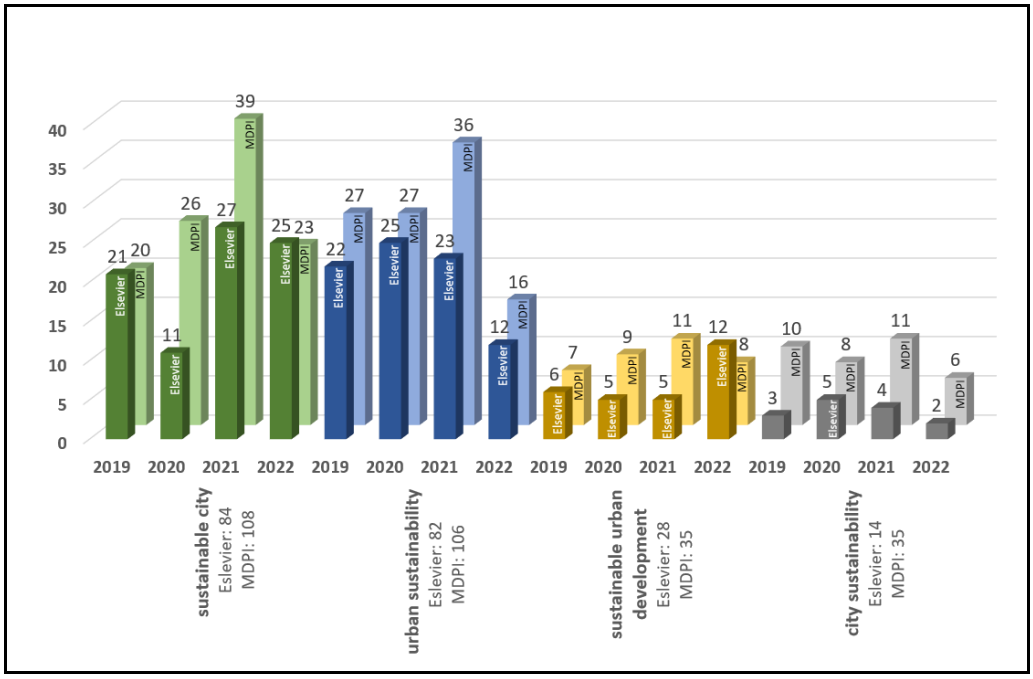

Fig. 2: Distribution of the identified recent articles on city sustainability published by Elsevier and MDPI based on the title's search keywords and years of publishing

4 RESULTS

As explained in the methodology section, nine articles were finally selected for further analysis concerning proposing an indicator system for measuring city sustainability. Chen and Zhang (2020) have measured the sustainability performance of 14 Chinese cities in the province of Liaoning by considering the linkage among multiple criteria. Based on the data availability within the complexity of urban systems, they have selected 21 indicators to include all subsystems with a suitable balance. Having a direct/indirect relationship to city sustainability, denoting the various facets of economy, society, and environment, and data accessibility and measurability were theirkeyconsiderationsindeveloping this indicator system (Chen and Zhang, 2020). In

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another researchanalysing the sustainability performancesof the 34 shrinking cities in Northeast China, they used the same criteria system (Chen and Zhang, 2021).

Li and Yi (2020) have measured the sustainability of 9 national central cities of China by an indicator system including 24 indicators from three interacting pillars of the sustainability concept. City sustainability supports the quantity and the quality of economic growth, aims at overall social and human progress, and indicates the sustainable use of natural resources and the ecological environment. However, they say that this set of indicators could represent only part of all aspects of urban sustainability because of the limitation of accessibility to the statistical data.

Tang et al.(2019) believe that city sustainability needs to be measured by an all-directional and multi-angled approach that can assess, monitor, and promote the sustainable development of cities. Hence, a complete, simple, and accurate city sustainability measuring index system should consider all effective factors of economy, society, and ecology. They have objectively evaluated the sustainability of 16 cities in the Anhui province of China through an index system that includes 39 indicators in three economic, social, and ecological development categories.

Yang et al.(2020) have suggesteda scientific base for decision-makers to measure and compare urban development directions by analysing the sustainability of 13 prefecture-level cities in the Beijing-Tianjin-Hebei region under various policy intervention scenarios. To that effect, a city sustainability evaluation model has been proposed following the principle of system dynamics and future policy scenarios, including sustainable development, business-as-usual development, partial sustainable development, extremely imbalanced development, and economic-growth-oriented development. Among numerous indicators characterising city sustainability, 20 accessible ones were selected in the Chinese urban management context, considering six subsystems of economy, livelihood, risk, environment, pollution governance, and resource.

Yi et al.(2019a), who have measured the sustainability of 17 Chinese cities in Shandong province with a set of 21 indicators, consider two main factors influencing city sustainability. Internal factors are the innate configuration of the city itself, including geographical location, climate, and natural resources. External factors are activities and states derived from the city, such as city size, population density, urban transportation, and social welfare.For measuring city sustainability, they have selected indicators by focusing on external factors fettered by the data availability. They were divided into economy addressing the quantity and quality of economic growth and development, society considering the basic demands of current and future generations, and environment fulfilling the basis of city sustainability.

In other studies, theyhave measured the sustainability level of 13 Chinese cities in the Capital Economic Circle and 15 sub-provincial cities in China from the Multi-Criteria Decision Making perspective. For the indicator system, they have considered comprehensiveness as a reflection of city sustainability by the economy, society, and environment, measurability as data accessibility to allow practical measurement, objectiveness as focusing on the actual objective performances, and stability as being relatively constant in responding to a long-term process. Accordingly, the indicator system includes 18 economic, social, and environmental indicators(Yi et al., 2019b and 2021).

Zhou et al.(2021) believe that the indicator system for measuring city sustainability should consider three social, economic, and environmental systems to achievesustainability. Accordingly, they've developed an indicator system for measuring the profit of the economic system, the benefits of the social system, and the rationality of the environmental system. It includes 24 indicators used to analyse the sustainability performances of 14 cities in the province of Liaoning. However, this set cannot entirely represent all aspects of city sustainability due to the data accessibility limitation and cannot be completely independent because of the partial overlap.

Followingthe analysis of existing research and case studies (Chen and Zhang, 2020 and 2021; Li and Yi, 2020; Tang et al., 2019; Yang et al., 2020; Yi et al., 2019a, 2019b, and 2021; Zhou et al., 2021), an indicator system was developed and proposed for measuring city sustainability. Those indicators were selected in the proposed indicator system for measuring city sustainability, which were atleast repeated and used four times or more in these studies. Consequently, as Fig. 3 and Table 3 show, it includes the 21 most frequent indicators for measuring city sustainability based on the three main dimensions/subsystems of economy, society, and environment. Concerning their effects on city sustainability, they were categorised into two attributes/properties of benefit: the greater criterion value is better for city sustainability and cost: the lesser

criterion value is better for city sustainability. As stated in the analysed studies, this indicator system cannot measure all aspects of city sustainability and will also be affected by the limitation of available and accessible data.

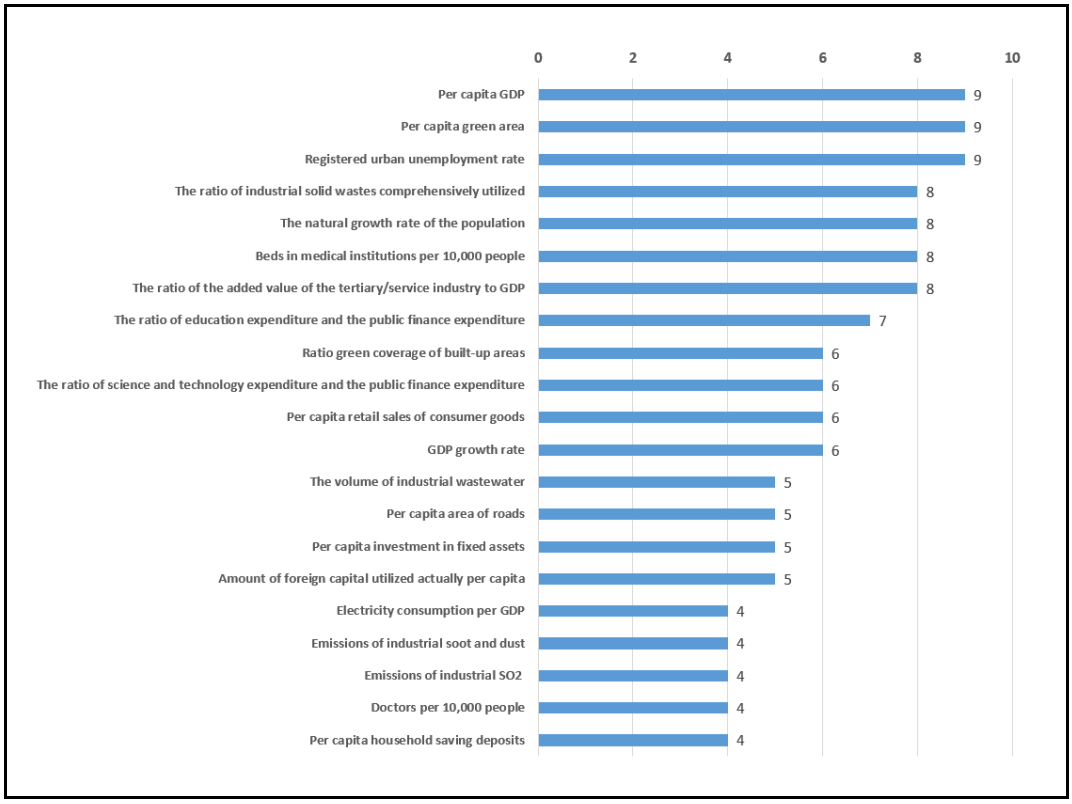

Fig. 3: Most frequent indicators for measuring city sustainability ranked by the number of the studied indicator sets in which have appeared (Chen and Zhang, 2020 and 2021; Li and Yi, 2020; Tang et al., 2019; Yang et al., 2020; Yi et al., 2019a, 2019b, and 2021; Zhou et al., 2021)

Economy		
Indicator	Unit	Property
Per capita GDP	Currency	Benefit
The ratio of the added value of the tertiary/service industry to GDP	%	Benefit
GDP growth rate	%	Benefit
Per capita retail sales of consumer goods	Currency	Benefit
Amount of foreign capital utilized actually per capita	Currency	Benefit
Per capita investment in fixed assets	Currency	Benefit
Per capita household saving deposits	Currency	Benefit
Society		
Indicator	Unit	Property
Registered urban unemployment rate	%	Cost
Beds in medical institutions per 10,000 people	Bed/104people	Benefit
The natural growth rate of the population	%	Benefit
The ratio of education expenditure and the public finance expenditure	%	Benefit
The ratio of science and technology expenditure and the public finance expenditure	%	Benefit
Per capita area of roads	m2	Benefit
Doctors per 10,000 people	Person/104people	Benefit
Environment		
Indicator	Unit	Property
Per capita green area	m2	Benefit
The ratio of industrial solid wastes comprehensively utilized	%	Benefit
Ratio green coverage of built-up areas	%	Benefit
The volume of industrial wastewater	Ton	Cost
Emissions of industrial SO2	Ton	Cost
Emissions of industrial soot and dust	Ton	Cost
Electricity consumption per GDP	kWh/Currency	Cost

Table 3: Proposed indicator system for measuring city sustainability (Chen and Zhang, 2020 and 2021; Li and Yi, 2020; Tang et al., 2019; Yang et al., 2020; Yi et al., 2019a, 2019b, and 2021; Zhou et al., 2021)

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5 CONCLUSION

City sustainability as an emergent concept directly contributing to the quality of increasing urbanisation is an attractive and popular research field in a broad range and at the front of numerous scientific inquiries recently. Measuring city sustainability could provide the possibility to know the status of cities as an important reference for sustainable urban development. Meanwhile, a comprehensive functional indicator system, including accurate indicators often challenged by available and accessible data, is the first point of measuring city sustainability. This study brings a theoretical and conceptual approach to this significant area through a systematic literature review of current research and experiences measuring city sustainability, including existing frameworks, indicator systems, and case studies.

Accordingly, an indicator system was developed and proposed to measure city sustainability. It includes the 21 most frequent indicators based on the three main dimensions/subsystems of economy, society, and environment. Concerning their effects on city sustainability, they were categorised into two attributes/properties of benefit: the greater the criterion value is better for city sustainability and cost: the lesser the criterion value is better for city sustainability. Thus, seven indicators measure the economic dimension, sevenconsider the social dimension, and seven address the environmental dimension. Conducting empirical case studies in future further research following the proposed indicator system will complement the path of this research. At the same time, it will be accompanied by weighting approaches and aggregating methods as another significant issue concerning measuring city sustainability.

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