Towards Sustainable Urban Development: Promoting Urban Sustainability Assessment in China, Taking Xiamen as an Example

Yuwei Zhao*
School of Architecture and Urban Engineering, Xiamen University, Xiamen, Fujian, 361000, China

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Abstract: As achieving sustainable urban development is vital to the future of the world, there is much focus on promoting urban sustainability assessment in Chinese cities. This study presents a set of adaptive models, an assessing framework, and the indicator systems for measuring the two goals of urban sustainability in China, taking Xiamen, for example. The study promotes the urban sustainability assessment by modifying the coupling coordination framework and applying the UN Sustainable Development Goals (SDGs). The findings suggest that the cosmos model is suitable to refine the coupling coordination model. Additionally, the framework and indicator systems built in this study promote urban sustainability assessment as they can detect potential problems, develop urban characteristics, and effectively utilize SDGs' advantages. In closing, compared with previous studies, this paper offers a practicable approach for research institutes, urban managers, and the public to measure urban sustainability, thereby promoting urban sustainability through the adjustment and development of urban planning, construction, and management.

1 INTRODUCTION

For the long-term prosperity of man and the planet, achieving sustainable urban development has become a global concern in the past several decades. China has experienced a dramatic urbanization process, which has brought serious challenges of environmental degradation (Shen, et al. 2017). Therefore, Chinese cities need to achieve sustainable development. Because the environmental carrying capacity restricts social equity and economic efficiency (Giddings, Hopwood, O'Brien 2002), the goals of urban sustainability can be interpreted as the transformation of environment pressure from positive growth to zero or negative growth and the realization of positive growth in the economy and society. Since economic and social development is a process of urbanization, and urbanization is an economic and social phenomenon the evaluation of the sustainability of urbanization is the evaluation of the sustainability of the economy and society. However, the achievement of urban sustainability acquires more than goals. It also relies on evaluating the sustainable progress because the evaluation can detect deviation of development when it occurs and help cities develop in the sustainable direction. Thus, an assessing framework and adequate indicators that can reflect the implementation status of two sustainability goals are vital to Chinese cities.

17 sustainable development goals (SDGs), proposed by the UN in 2015, have been authoritative criteria for evaluating urban sustainability because of their possibility of providing more balanced and integrated indicators (Zinkernagel, Evans, Neij 2018). Applying the SDGs to create an assessing framework and indicators is a common strategy. SDGs have low operability, and scholars have solved it in two ways: building complementary frameworks (Costanza, et al. 2016, Vanham, et al. 2019) and integrating or dismantling the SDGs (Griggs, et al. 2014, Kynclova, Upadhyaya, Nice 2020). However, the economy and society sustainability goals of cities have rarely been evaluated directly. This is due to the integrity of SDGs. One SDG usually guides the sustainable development of economic, social, and environmental dimensions simultaneously, so the indicators derived from SDGs often simultaneously reflect the sustainability status of three dimensions. Consequently, the description of the two goals of urban sustainability is often vague.

Besides, the two goals of urban sustainability have an interaction effect, so scholars have researched to accurately reflect the relationship between the two goals. One of the most popular

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models is “the coupling coordination model” (Fang, Wang 2013, Wang, Ma, Zhao 2014), in which the relationship between urbanization and environment is interpreted as simultaneously mutual restraint and promotion (Fang, Wang 2013). Due to its comprehensiveness, this model can strongly reflect the interaction effect of urbanization and the environment. However, the main research method is to calculate urbanization and environment index based on indicators rarely related to sustainability and to use the indexes to analyze the coupling coordination relation. Few previous studies have investigated the evaluation of sustainable development of urbanization and the environment.

This paper aims to promote the urban sustainability assessment in Chinese cities. The study analyzes and summarizes the current assessment approaches to achieve the following objectives: (1) identify the suitable models for urban sustainability assessment in Chinese cities, (2) build a compatible assessing framework and the following indicators for measuring sustainable development. Based on the existing approaches, the paper builds the assessing framework and indicators that can accurately describe the two goals of urban sustainability and their implementation situation. These can fill the research gaps and promote the urban sustainability assessment. Furthermore, the paper can provide a good reference of practicable framework and indicators for research institutes, urban managers, and the public to monitor the development status, thereby urges the cities to develop sustainably.

2 METHOD

2.1 Overview

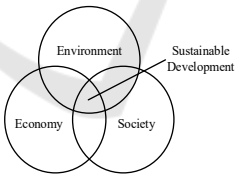
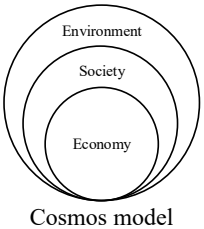
The study focused on improving the assessing approach to achieve sustainable urban development in China. After analyzing the existing approaches, this paper selected the cosmos model as the research basis and modified the coupling coordination model to build the assessment framework. Furthermore, the study applied SDGs to generate indicators, then used CRITIC and entropy methods to determine the weight of each indicator. Because the Xiamen government actively improved urban sustainability through planning, construction, and management, meanwhile the existing information was relatively complete. Thus, the study chose Xiamen as the research object, the location of which is shown in figure 1.

Figure 1: Location and range of Xiamen, China..

2.2 Model and Framework for Assessing Sustainable Development Status

Table 1 presents two widely-used models for describing the three dimensions of sustainable development – economy, society, and environment.

Table 1: Two models of sustainable development. (Synthesis from the literature (Mebratu 1998)).

Models (with figures)	Description
 Crossing model	This model describes the three dimensions as three circles interconnected with each other equally.
 Cosmos model	This model suggests that since environmental carrying capacity restricts social equity, which restricts economic efficiency, the relationship among the three dimensions should include each other.

The cosmos model conforms to the core concept of sustainable development, “developing under the environmental carry capacity”. This model can best reflect the urban sustainability of China since, in recent years, China has paid more attention to the

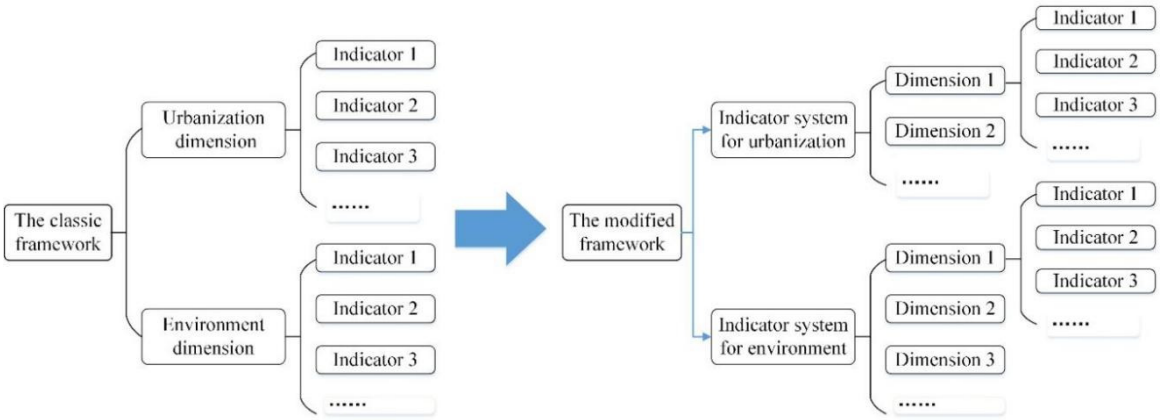


Figure 2: Modification of coupling coordination model.

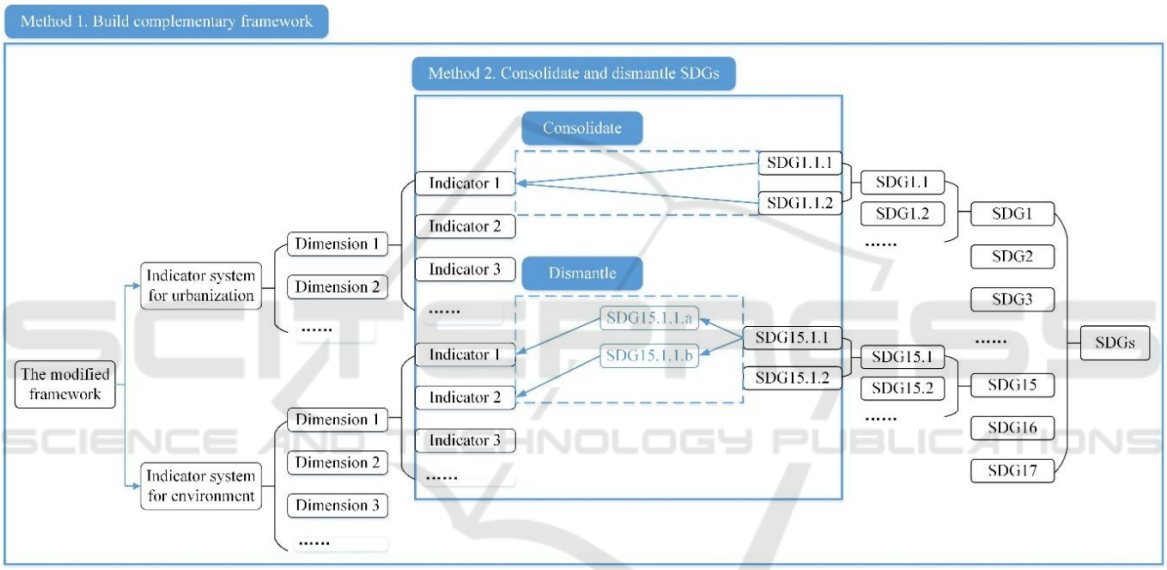


Figure 3: Methods used for selecting indicators.

environmental carry capacity when evaluating sustainable urban development. Therefore, this study used the cosmos model to analyze the relationship of economy, society, and environment.

In addition, because the coupling coordination model can accurately reflect the interaction effect of urbanization and the urban environment, the study chose this model to build the framework. However, the model neglected the sustainable development status of urbanization and the environment, so the study modified the classic coupling coordination model as figure 2 displays.

The classic coupling coordination model contained one indicator system with two dimensions – urbanization and environment. It limited the number of indicators to not fully reflect all aspects of urbanization and the environment. Therefore, the study split it into two indicator systems. Furthermore, the modified framework needed new indicators that can reflect the implementation of sustainable developments.

2.3 Criteria for Selection of Indicators

Figure 3 illustrated the methods used for selecting indicators. The study combined the modified coupling coordination model with SDGs to build a complementary assessing framework, then consolidated and dismantled SDGs to generate indicators.

The paper firstly summarized frequently-used indicators from the existing sustainability assessments of urbanization and the environment. Secondly, according to the urban characteristics of

Xiamen and the older indicator systems Xiamen has used, the study determined the required SDGs when building the indicator systems. Then the study built the two indicator systems based on the above research. In addition, the study added the missing aspects of sustainable urban development in the classic model based on the SDGs. When applying the SDGs, the paper consolidated and dismantled SDGs to generate indicators. Some official SDG indicators have low operability, so the paper used authoritative indicators from existing sustainability indicator systems to replace them.

2.4 Method for Calculating Weight

1) Data normalization. To eliminate the impact to assessment caused by different dimensions of the indicators, the study used forward processing for positive indicators and reversed processing for reverse indicators. Thus, the normalized values of all indicators are within the range of [0-1].

2) Endow weight method. The study firstly applied the CRITIC method to determine the weight of the indicators. CRITIC method calculated the weight based on the contrast intensities (represented by standard deviation) and conflicts (represented by correlation coefficient) between the indicators. Secondly, the study used the entropy method to calculate another weight for each indicator. The entropy method determined the weight according to the information entropy of the indicators. The greater the information entropy, the more information the indicator could provide, which means the more important the indicator would be in the assessment. Therefore, the greater the index weight is. Finally, the study calculated the arithmetic means of weights of the CRITIC method and the entropy method and obtained comprehensive weights, which gave weights to the indicator systems.

3 RESULTS AND DISCUSSION

3.1 The Assessing Framework and the Following Indicators

This paper applied the cosmos model and modified the coupling coordination model to build the indicator systems of sustainable development of urbanization and the environment, as shown in Table 2 and Table 3. In each table, the column “target direction” shows whether the value of indicators increases or decreases when urban sustainability promotes. The column “corresponding SDGs” represents the SDGs each indicator derived from.

3.2 Explanation and Inference

The study built two indicator systems based on the classic coupling coordination model and SDGs to promote the assessment for sustainable urban development in Xiamen. Building two indicator systems ensure that each system has sufficient indicators to represent all the related aspects of urban sustainability. By using the classic coupling coordination model, the two indicator systems can

Table 2: The indicators of sustainable development of urbanization.

Subgoals		Indicators	Target direction	Corresponding SDGs	Weight
C1 economic urbanization (0.412)	C3	The annual growth rate of GDP per capita (%)	+	SDG8.1	0.057
	C4	The ratio of the added value of the secondary and tertiary industries in GDP (%)	+	SDG8.2	0.048
	C5	GDP per capita (Yuan)	+	SDG8.1	0.062
	C6	Population density (persons/km^2)	+	SDG11.3	0.077
	C7	The ratio of the urban population in total population (%)	+	SDG11.3	0.078
	C8	The gross output value of tourism (billion Yuan)	+	SDG8.9	0.090
	C9	The ratio of total retail consumption in GDP (%)	+	SDG8.4	0.096
C2 social urbanization (0.588)	C10	The ratio of land consumption rate to the population growth rate (%)	-	SDG11.3	0.128
	C11	Number of hospital beds per 10,000 people	+	SDG3.8	0.053
	C12	Urban road area per capita (m^3/capita)	+	SDG11.2	0.082
	C13	Urban drainage pipe length per capita (m/capita)	+	SDG11.5	0.054
	C14	Green space area per capita (m^3/capita)	+	SDG11.7	0.091
	C15	Public vehicles per 10,000 people	+	SDG11.2	0.084

Table 3: The indicators of sustainable development of the environment.

Subgoals		Indicators	Target direction	Corresponding SDGs	Weight
E1 Environment endowment (0.136)	E5	Water resources per capita (m^3/per capita)	+	SDG6.4	0.088
	E6	The ratio of good air quality (%)	+	SDG11.6	0.048
E2 environment elements (0.325)	E7	Green coverage rate in built-up areas (%)	+	SDG15.2	0.063
	E8	The total quantity of marine fishery products per year (tons)	-	SDG14.4	0.086
	E9	The volume of total surface water resources (m^3)	+	SDG6.6	0.095
	E10	The volume of total groundwater resources (m^3)	+	SDG6.6	0.081
E3 environment respond (0.307)	E11	Harmless disposal rate of domestic garbage (%)	+	SDG11.6	0.129
	E12	The volume of wastewater disposal per year (m^3)	+	SDG6.3	0.057
	E13	The volume of domestic garbage disposal per year (tons)	+	SDG11.6	0.066
	E14	Average annual concentration of PM2.5 (μg/m^3)	-	SDG11.6	0.061
E4 environment pressure (0.232)	E15	The volume of industrial wastewater discharge per capita (tons/capita)	-	SDG9.4	0.068
	E16	SO^2 emissions per capita (kg/capita)	-	SDG9.4	0.041
	E17	Industrial dust emissions per capita (kg/capita)	-	SDG9.4	0.047
	E18	The ratio of acid rain incidence (%)	-	SDG6.3	0.076

assess the implementation status of the two goals of urban sustainability in China, as the indicator systems respectively output the comprehensive indexes of sustainable development of urbanization and environment. Furthermore, by corresponding each indicator with an SDG, the indicator systems can reflect the sustainability status of urbanization and the environment, avoiding the withdraws of the classic coupling coordination model. Hence, the framework and the following indicator systems built in the study are practical and advantageous to assess the urban sustainability of Xiamen.

3.3 Comparison

When comparing the results to older indicator systems, whether from older studies or practices of indicators by research institutes or urban administration committees, it must be pointed out that the indicator systems in this study state an academic superiority as below.

1) Superiority in finding the problems in sustainable development progress. Firstly, while the older indicator systems could not assess problems that occurred in sustainable urban development progress (Shen, Zhou 2014), the ones proposed in this study are good at detecting them. For example, in Xiamen's urbanization process, a major obstacle in urban construction is the "urban villages", which are rural areas left behind in the process of rapid urbanization. They impede further urbanization because their social and spatial structures do not allow them to participate in economic and social development. Therefore, the study set "The ratio of the urban population in total population (%)" in the urbanization indicator system to monitor the changes in the population of urban villages, reflecting the speed of the transformation of urban villages. In addition, there are indicators assessing surface and underground water resources in the environment system, as water-deficient has been a long-term environmental management problem in Xiamen. The environment system also includes "The ratio of acid rain incidence (%)", an uncommon indicator among older studies. Although acid rain has been under control in many cities, it still is a problem in Xiamen, as the ratio of acid incidence in 2020 is 60%, far above the normal levels of 20%. These indicators can draw the government's attention to Xiamen's problems, which is an advance in measuring urban sustainability.

2) *Superiority in embodying urban characteristics.* Secondly, major older studies often give standard indicator systems, whereas this study considers urban characteristics. In the urbanization system, since Xiamen concentrates on the development of the sustainable tourism industry and urban public transport such as BRT, the study chooses indicators like "Public vehicles per 10,000 people" and "The gross output value of tourism (billion Yuan)". In the environment system, as Xiamen is "a model city for beautiful China", the indicators aim to reflect land and water ecological

restoration status, which leads to the choice of indicators like "Green coverage rate in built-up areas (%)" and "The total quantity of marine fishery products per year (tons)". Concentrating on demonstrating urban characteristics, the indicator systems in the study can help improve Xiamen's distinctiveness, which prevents Xiamen from developing homogeneously. In brief, this superiority promotes the assessment and the development of urban sustainability in Xiamen.

3) *Superiority in applying the SDGs.* In addition, the indicator systems in the study are more effective in exploiting the advantages of SDGs to the full than older studies. The study uses two approaches to achieve that. First, the study utilizes the practicable and advanced indicators SDGs framework brought about. For example, scholars tend to use traditional indicators like "Urban area per capita (m2)". However, this study uses SDG11.3.1 "The ratio of land consumption rate to the population growth rate (%)". SDG11.3.1, which demonstrates sustainable urbanization and capacity for participatory, is more advanced and precise than traditional indicators. Second, this study uses part of the SDGs rather than all SDGs. While the SDGs interact with each other (Pradhan, et al. 2017), using all SDGs may make the assessment results ambiguous and confusing. In the study, only SDG3, 6, 8, 9, 11, 14, 15 are used in building indicator systems, making the indicator systems clear and comprehensive. In short, applying SDGs provides Xiamen with more advanced indicators. As a result, it has advantages in helping Xiamen realize the international urban sustainability standards.

In conclusion, contrary to the older indicator systems, the indicator systems in this study are more applicable to Xiamen and are better at measuring urban sustainability. Therefore, the indicator systems in the study can promote sustainable urban development in Xiamen.

3.4 Interpretation

As discussed above, the indicator systems in the study can be applied to various circumstances to improve the sustainable urban development of Xiamen. Research institutes can use the framework and indicator systems to produce objective assessment reports. An official report may be confusing in China as the report states that the development is sustainable and positive. At the same time, the phenomena observed in the city suggest it is not the case. This is because the government prefers to choose indicators that can highlight development achievements, neglecting the potential problems that occurred during development. A report from research institutes can reduce issues like these, expose the problems Xiamen has, and objectively reflect urban sustainability status.

Consequently, the framework and indicator systems can provide accurate data for the city managers, which has significance for promoting the urban sustainability of Xiamen. With these data, city managers can manage urban resources effectively, formulate better urban planning, and guide the upgrading of Xiamen's urban construction (Wang, Ma, Zhao 2014). Furthermore, the assessment produced by the framework in the study let the public know the urban sustainability status of Xiamen. In general, China has a low public engagement of participating the sustainability supervision (Shen, Zhou 2014), result from the asymmetric information between the public and the government. The assessment report based on the framework in the study can compensate for the information gap, enhance public participation, and provide favorable suggestions for the realization of urban sustainability from the perspective of urban planning, construction, and management.

4 CONCLUSION

This paper promoted urban sustainability assessment in China by structuring an adaptive assessing framework and the following indicator systems. In summary, the study used the cosmos model and the coupling coordination model to redevelop an assessment framework and indicator systems of urbanization and the environment for Xiamen. The assessing framework and indicator systems compensate for the withdraws of the old ones – inadequate indicator number and deficiency in evaluating the two goals of urban sustainability. Compared with the older ones, the framework and indicators proposed in the paper promote the urban sustainability of Xiamen in three ways, namely improving the capability of detecting problems, embodying urban characteristics, and utilizing the advantages of SDGs. Furthermore, by improving urban sustainability assessment, the study urges Xiamen to develop sustainably. It is because these findings are practicable for research institutes to provide assessment reports and urban sustainability data. These data are crucial for urban managers and the public to enhance urban sustainability, because they use the data as the reference to improve urban

resource management, urban planning, and urban construction.

Future research should be devoted to developing urban sustainability assessment, and how the evaluation results can improve sustainable urban development. On one hand, future research should test the framework with empirical studies, and use the methods of generating indicators in this paper to carry out researches on other cities. On the other hand, future investigations should explore methods of using assessment results to improve sustainability. For example, urban managers can incorporate some particular indicators' values into the performance management system of urban construction. In summary, the benefit of improving urban sustainability assessment is evident, and structuring an assessing framework and indicators is an effective way to promote sustainable urban development.

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