The Construction of Green City Evaluation Index System and its Application in Shanxi Province

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Abstract. In the world, a series of problems such as regional climate change have gradually emerged, and countries around the world are committed to developing green cities and actively creating new ideas on climate change. This paper takes green city evaluation as the direction, constructs the framework of "target-indicator-criterion" indicator system, selects several evaluation indicators, a Green City, Indicator System, Evaluation.nd establishes the green city indicator evaluation model. It is also applied to Shanxi Province to study and analyse the current situation of green city development in Shanxi Province and propose countermeasures.

Keywords: Green City, Indicator System, Evaluation.

1. Introduction

The problems between urban development and resources and the environment are becoming increasingly evident as society and the economy continue to develop: energy shortages, pollution of the natural environment, traffic congestion, climate change, etc. In 2020, China formally put forward its dual carbon targets in the United Nations General Assembly: aiming to achieve carbon peaking by 2030 and carbon neutrality by 2060. Therefore, the development of green cities based on the double carbon goal is crucial. China is the largest developing country in the world, and the problem it faces is how to promote economic development and the improvement of people's quality of life [1].

The technical route of this paper is to analyse and study the current situation of domestic and international research on green cities, establish a green city evaluation index system, which are five evaluation index subsystems, namely ecological environment, urban development, environmental resources, social development and green management, select the weight calculation method of entropy value method, carry out the construction of comprehensive evaluation index system, and carry out empirical analysis on the construction of green cities in Shanxi Province.

2. Review of the literature

2.1 Understanding of the concept of green cities by scholars in China

Early on, Chinese scholars had a more profound understanding of green cities. Early scholars believed that the development of green cities required top-down and bottom-up all-round development, government policy support, technical support from the market and citizens' conceptual support, one of which was indispensable [2].

As the research progresses, the analysis of urban development models and indicator components begins. In terms of the analysis of the composition of indicators, the goal of developing low-carbon, compact and recycling cities is proposed; in terms of the development model, it is more reflected in the design of the system. Different cities have different urban characteristics, cultural heritage and historical accumulation formed over the years, so the corresponding urban management methods and systems should be in harmony with the city's own system, economy, culture, history and values [3].

2.2 Analytical exploration of green cities by scholars in China

In general, the analysis and exploration of green cities by scholars in China has focused on the local context, with different cities creating different forms of green development models, analyzing

various aspects of policy, environment and transport, and more on the macro level to propose optimal green development countermeasures.

For cities with advanced green development, scholars in China have conducted preliminary analysis and research. For example, for the construction of a green city in Chongqing, the role of fortress greening is proposed, and the ideas suitable for the construction of a green city in Chongqing are put forward according to its own topographical characteristics and local conditions [4]; for the development of a green city in Shanghai, the advantages of Shanghai's developed economy and trade should be seized, and the concept of green city development should be applied to reform the industrial structure and so on [5]; through the construction of a green city in Xiongan New Area The current situation and development direction of the Xiong'an New Area are studied, and the need to improve relevant regulations, strengthen management, and implement green transportation and other solutions to strengthen the construction of green cities is proposed [6].

With the depth of research, systematic sustainable development is further penetrated into the study of green city development. In for the development of intensive green cities in the Guangdong-Hong Kong-Macao Bay Area, the development idea of creating an intensive green city is the goal [7]; the analysis of Shenzhen becoming the first green city in China has been conducted, and it is concluded that Shenzhen's urban landscape has advanced design ideas in terms of architecture, transportation and ecology, which can comply with the requirements of building a green city [8].

2.3 Status of research on green cities by foreign scholars

Early foreign scholars tended to select specific and refined indicators for statistical analysis. Japanese scholar Masaharu Yanagita conducted a statistical analysis of carbon emissions from households, transportation and industry in Japan, and proposed specific measures to reduce emissions in terms of building structure, low-carbon transportation, industrial layout and the use of new energy technologies [9]; Hillman and other scholars specifically analyzed data from eight cities in the United States, comparing the carbon emissions from four types of energy used within the city: food, water, fuel and cement, as well as cross-border transportation and production processes outside the country. They have also analyzed data from eight cities in the United States, comparing the carbon emissions of four types of energy used within the city: food, water, fuel, cement, and cross-border transportation and production processes outside the city, and promoting research on the urban carbon cycle and carbon metabolism [10].

As research progresses, the selection of indicators for green city development has become more systematic, and unremitting efforts have been made in the direction of innovative green city development concepts and innovative urban forms. Among them, foreign scholars have proposed the concept of "urban village communities" on the basis of compact city design, promoting sustainable urban development from the perspective of the city itself, effectively shortening transportation distances and reducing pollution emissions through the sustainable and comprehensive use of public infrastructure, and promoting urban development [11]; they have proposed the path of green city branding for sustainable urban development, by reflecting on the two winning cities of the European Green Capital Award: Stockholm and Hamburg [12]. It is concluded that through this award, local governments can draw public attention to the economic benefits that can be derived from increased exports of green technologies and ecotourism.

2.4 Analysis of the overall research situation

Domestic and foreign research in green city construction have advanced theories and countermeasures and have achieved results, China's exploration of green development models in different cities are very much focused on local conditions, for some regions there may still be room for in-depth research on the construction of a city green city status quo, through known data to analyse, build evaluation index system, the existence of problems to put forward reasonable and effective We will continue to pay attention to the direction of the current situation of green cities in a city, analyse

the known data, build an evaluation index system, and propose reasonable and effective solutions to the problems.

3. Green City Evaluation Establishment of the Indicator System

3.1 Principles for the construction of the indicator system

The establishment of the assessment system directly affects the authenticity, accuracy and comprehensiveness of the assessment results, so care should be taken when building the assessment system. In establishing our green economy assessment system, the fundamentals and specifics of the assessment were taken into account and basic guidelines for establishing this assessment system were proposed.

(1) Scientificity. In the green city assessment system, the selection of each indicator, the source of data, the analysis of data and the analysis of data should be based on scientificity, that is to say, the selection of indicators should truly reflect their intrinsic meaning and essence.

(2) Representativeness. The ability of the established assessment system to objectively reflect the level of green city development in the region depends largely on the quality of the individual indicators, with high indicators containing a large amount of information and being well representative.

(3) Systematic. A comprehensive assessment system is set up by considering various aspects such as economy, energy, environment, science and technology, and making a comprehensive assessment from four aspects: economic development, energy emissions, environmental protection and scientific and technological progress.

(4) Accessibility. It is important to ensure the availability of information in the selection of each indicator so that the degree of green city development in each region can be accurately measured, thus providing quantitative reference for governments at all levels to formulate corresponding green city development strategy decisions.

(5) Innovation. In recent years, as the development of green cities in China has become a popular topic, people have not established an authoritative assessment mechanism to evaluate them, and scholars have established corresponding assessment systems according to their own objectives.

3.2 Establishment of the indicator system

Based on the principles of evaluation system construction, this paper constructs an evaluation system framework with three levels: target level, criterion level and indicator level, based on the connotation of green city development.

(1) Target layer

The aim of this paper is to assess the degree of development of a green city, using the degree of development of the city as an indicator. This value provides a comprehensive picture of the city's economic development, energy emissions, environmental protection and scientific and technological level.

(2) Guideline layer

The guideline level in this paper is a specification of the target level, on the basis of which a specific hierarchy of indicators is proposed, namely the economic system, the energy system, the environmental system and the science and technology system.

(3) Indicator layer

The indicator hierarchy is an important basic indicator to measure the guideline level. Through previous studies on the assessment of green city development, a green city development evaluation system including 16 specific indicators was constructed based on the feasibility of the data, using frequency statistics, as shown in the Table1.

Table 1 Green City Indicator System

Target level	Guideline level	Indicator layer	Indicator Direction
Green City Level of development Evaluation system	Economy	GDP per capita (yuan/person)	Positive
		Share of tertiary sector (%)	Positive
		Income ratio between urban and rural residents	Negative
		Urbanisation rate (%)	Positive
	Energy	Energy consumption per unit of GDP (million tonnes of standard coal/yuan)	Negative
		Energy consumption of gross industrial output value (tonnes of standard coal/yuan)	Negative
		COz emissions per capita (million tonnes/person)	Negative
		CO2 emissions per unit of GDP (t/y)	Negative
	Environment	Green space per 10,000 people (ha)	Positive
		Parkland area per capita (ha/million people)	Positive
		Greening coverage of built-up areas (%)	Positive
		Number of days with air quality above Level 2 (days)	Positive
	Technology	Integrated utilization rate of industrial solid waste (%)	Positive
		Industrial fume removal rate (%)	Positive
		Harmless disposal rate of domestic waste (%)	Positive
		Urban domestic sewage treatment rate (%)	Positive

3.3 Explanatory notes on indicators

(1) Economic sub-system indicators

The economic aspect of a green city is reflected in the development of a low carbon economy, which requires an index that reflects the characteristics of the economy to reflect economic development. In this paper, four indicators are selected: GDP per capita, the proportion of tertiary industry, the income ratio between urban and rural residents, and the urbanisation rate.

(2) Energy sub-system indicators

Energy consumption is an important indicator affecting CO2 emissions. It can be used as an important measure of China's green development and an important target for achieving energy saving and emission reduction, but it releases a lot of CO2 in the process of use, so when choosing an energy system, it is important to take into account the amount of energy consumption and CO2 emissions. In this paper, four main economic development indices are chosen: energy consumption per unit of GDP, energy consumption of gross industrial output, CO2 emissions per capita and CO2 emissions per unit of GDP.

(3) Environmental sub-system indicators

When developing a green city, the harmonious development of man and nature must be taken into account. With the importance people attach to green areas, the development of green areas plays a good role in promoting environmental protection in cities, and the increase of green areas can reduce the content of CO2 in the atmosphere, so in the selection of urban green areas, the area of park green areas per capita, the green areas of built-up areas and the level of atmospheric pollution are evaluated.

(4) Science and technology sub-system indicators

The development of green cities cannot be achieved without the strong support of science and technology. Given that the aim of our innovative technology is to achieve low pollution, low energy consumption and low emissions, the evaluation criteria of the technology system are selected from

the perspective of technology effects. The comprehensive utilisation rate of industrial solid waste, the removal rate of industrial smoke and dust, the harmless treatment rate of domestic waste and the treatment rate of urban domestic wastewater are chosen and are therefore positive indicators.

4. Construction of the evaluation model

4.1 Standardisation of indicators

In general, there are two kinds of indicators in the evaluation system, positive and negative, and each indicator has a different scale, so all indicators need to be standardized before building the model, and the common formula is as follows.

Positive indicators.

$$X^*_{ij} = \frac{X_{ij} - \beta_{ij}}{\alpha_{ij} - \beta_{ij}} \tag{1}$$

Negative indicators.

$$X^*_{ij} = \frac{\alpha_{ij} - X_{ij}}{\alpha_{ij} - \beta_{ij}} \tag{2}$$

Where Xij is the value of indicator j for municipality i, $(i = 1,2,\text{L}\ ,n; j = 1,2,\text{L}\ ,m)$, m is the number of prefecture-level municipalities, n is the number of indicators, and X^*_{ij} is the standardised value of each indicator.

4.2 Calculation of the weights of the indicators

In the literature on the assessment of the extent of low carbon economic development at home and abroad, most scholars mainly use the hierarchical analysis method and the Delphi method, etc. Because the subjective assignment method is based on the subjective judgement of experts, which is highly subjective, the weights of the professionals chosen are not the same, and the weights given may not reflect the real situation, so this paper uses the objective assignment method, i.e., the entropy method, to calculate its weights.

The entropy weighting method is an objective method of assigning weights that are subject to different levels of subjective factors when using an artificial approach to rights allocation, and entropy is a good solution to this problem of inappropriate distribution due to artificial causes. The entropy weighting method is based on the data itself, which is judged by the index variation factors that the indicator can provide. It is done as follows.

The general steps for determining the indicator weights by the entropy method are as follows.

Indicator weighting is calculated.

$$h_{ij} = b_{ij} \Big/ \sum_{i=1}^{n} b_{ij}, (i = 1,2,\text{L}\ \ n; j = 1,2,\text{L}\ \ m) \tag{3}$$

Calculate the entropy value of the indicator.

$$f_j = -\frac{1}{\ln n} \sum_{i=1}^{n} h_{ij} \ln h_{ij}, (i = 1,2,\text{L}\ \ n; j = 1,2,\text{L}\ \ m) \tag{4}$$

Calculate indicator weights.

$$v_j = -\frac{1 - f_j}{m - \sum_{j=1}^{m} f_j} (j = 1,2,\text{L}\ \ m) \tag{5}$$

5. Application of Green City Evaluation Index System - An Example of Shanxi Province

5.1 Data sources.

This paper establishes a framework for evaluating the green economy of cities in Shanxi Province, and extrapolates the development of the green economy in Shanxi Province based on data from Shanxi 2017-2021, the main data being based on the Shanxi Statistical Yearbook (2017-2021) and the China Urban Statistical Yearbook (2017-2021).

5.2 Measurement results and analysis

By standardizing the indexes and using the entropy method to weighted calculate the indexes, the development status of Shanxi in 2017-2021 can be more objectively evaluated, so as to better reflect the dynamic development and regional differences between regions, and put forward corresponding policies and measures for the better and better development of Shanxi Province. The green city development status of cities in 2017-2021 is shown in the table.

Table 1 Results of calculating the weights of secondary indicators for the evaluation of green city development level in Shanxi Province, 2017-2021

Indicators	2017	2018	2019	2020	2021
Economy	0.460204	0.478581	0.417020	0337940	0.433191
Energy	0339753	0308607	0.408298	0.431440	0.364345
Environment	0.074335	0.102771	0.100062	0.067087	0.082622
Technology	0.125708	0.110041	0.074619	0.163534	0.119842

Table 2 Results of calculating the weights of the three-level indicators for the evaluation of green city development level in Shanxi Province, 2017-2021

Indicators	2017	2018	2019	2020	2021
X1	0.120011	0.150277	0.170000	0.182083	0.196487
X2	0.118055	0.153645	0.131561	0.115820	0.118863
X3	0.189870	0.184706	0.179756	0.159904	0.175817
X4	0.169041	0.176211	0.185970	0.180558	0.192950
X5	0.325480	0.251484	0.238499	0.186687	0.234396
X6	0.159041	0.153068	0.239032	0.399016	0.216407
X7	0.189999	0.279508	0.283969	0.227610	0.314801
X8	0325480	0.278885	0.238499	0.186687	0.234396
X9	0.212079	0.208081	0.246575	0.243552	0.241047
X10	0312949	0.350164	0.317451	0.309514	0.333699
X11	0.176895	0.233082	0.231760	0.245405	0.196944
X12	0.298076	0.208673	0.204215	0.201529	0.228310
X13	0.211033	0.220790	0.195562	0.143401	0.153661
X14	0.255685	0.330348	0.260185	0.257312	0.293734
X15	0.254560	0.239636	0.293174	0.388673	0.402667
X16	0.278722	0.209226	0.251079	0.210614	0.149939

5.3 Evaluation Analysis of Green City Indicators in Shanxi Province

(1) The two economic and energy subsystems play a large role in the overall degree of development, while the two ecological and scientific and technological subsystems are relatively weak. Because Shanxi Province is a resource-rich province, its overall development relies on a heavy industry dominated by coal mining, an industry that generates huge amounts of energy, especially coal, in the process of producing economic benefits, and thus the corresponding economic and energy subsystems have relatively high weights between them. This coal heavy industry approach to economic development in Shanxi Province generates significant environmental problems in the process of development and has relatively little investment in science and technology, so the corresponding ecosystem and science and technology subsystems have relatively lower weights.

(2) It is worth noting that the economic subsystem shows a significant trough in 2020, most likely due to the impact of the epidemic, thus showing that the sudden outbreak of the epidemic had an irreversible negative impact on economic development, but that the impact of the epidemic on the economy was gradually moderated as the province became more resilient to the epidemic. Conversely, it can be seen that the province's share of science and technology also increased significantly in 2020, reaching a five-year peak. It is clear that the province is actively developing science and technology and adhering to China's route to technological strength at a time when the epidemic is affecting national development.

(3) The scores for the environment show the greatest variation, while the scores for energy show the least variation, and their scores show an overall upward trend. In the past, the blind pursuit of development led to low ecological quality scores in the first year. With the introduction of emission reduction measures by local and national governments and the growing awareness of environmental protection among the people, there has been a positive impact on the protection and restoration of the ecological environment in China, resulting in a significant improvement in scores from the second year onwards, and this upward trend will continue until 2021. This indicates that the ecosystem has been optimised and has reached a relatively stable level. For the energy subsystem, the trend is towards a continuous increase in scores, indicating that Shanxi has made significant achievements in environmental protection, with an increase in existing production capacity, the use of more clean energy sources such as gas, the importance people attach to environmental protection, and the emergence of various new industries with low energy consumption, resulting in a decrease in the demand for fossil fuels.

6. Conclusion

The development of green cities needs to be combined with the actual situation of each region, according to local conditions, for its evaluation also needs to be analyzed from the data in reality. In this paper, from the perspective of the collection, collection and collation of relevant data at home and abroad, the entropy value method is used to construct a green city evaluation index system, also taking Shanxi Province as an example through the study of the index system, and analysing the development status of green cities in Shanxi Province, green cities is a broad and extensive vocabulary, due to my academic level as well as the limited drilling time, this paper is limited to the preliminary development degree and constraints of its I will continue to improve it in my future work. Although a great deal of research has been conducted both at home and abroad on China's low carbon economy assessment system, and various aspects of it have been analysed, an authoritative assessment system has not been established to date, and there are certain biases in the selection due to a lack of sufficient information, pending in-depth research and exploration.

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