China's Low-carbon Index System — Based on Map Analysis and Factor Analysis of CiteSpace

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Abstract. The low-carbon economy is an important policy for economic development that China is committed to, and it is of very positive significance to analyze its depth. In the context of such an era, China requires vigorous development of a low-carbon economy and strives to achieve the goal of "double carbon", but to assess whether a country or region is a low-carbon economic development, it is necessary to establish a scientific low-carbon index system (Cong, Yun, Xia, 2014). This paper uses the keyword co-occurrence map and cluster map of CiteSpace to explore the current development status of China's low-carbon index system. Moreover, there is no unity between the low-carbon index system and the national index system in various cities, the system research is not in-depth innovation, and the construction scale of low-carbon cities is not systematic. The factor analysis method is used to conduct empirical analysis, draw conclusions, and according to the conclusions, local governments should strengthen the standardization of the local index system, develop new green enterprises, explore and study new indicators, and provide a certain reference basis.

Keywords: Low-Carbon Economy, Low-Carbon Indicators, CiteSpace, Factor Analysis.

1 Introduction

The theory and practice of establishing low-carbon cities at home and abroad reveal that low-carbon cities aim to enable cities to achieve low-carbon development. This represents a development strategy, a development model, and a development concept. In 2014, some scholars proposed to carry out empirical research on the construction of a low-carbon economic index system in Beijing, Tianjin, and Hebei. To establish an evaluation index system for low-carbon economic development in the region (Bai, Zhao, 2015,Huang, Feng,2016), an in-depth analysis is conducted through SPSS software. However, a further summary of the literature analysis and research lacks on the construction of China's low-carbon index system in recent years, and that research presents somewhat one-sided views. Therefore, a reliable low-carbon index system should be comprehensively analyzed and studied. With a combination of CiteSpace

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and SPSS, this paper aims to explore the development status of the low-carbon index system in China through the co-occurrence map and cluster map of domestic literature and compare some index systems to avoid complicated indicators. Moreover, factor analysis and empirical research are used to systematically explore the rationality of indicators, and further pursue the low-carbon economy to build low-carbon cities. Then, through various analyses of CiteSpace and SPSS, the corresponding weights and indicators affecting the construction of low-carbon cities are found to offer measures and suggestions and provide a reference for the research methods of China's low-carbon economic development.

2 Current Situation of China's Low-Carbon Index System

CiteSpace uses keyword nodes and centrality to determine the importance of the selected parameters and reveals the research hotspots by keyword mapping. As shown in Figure 1, there are 61 nodes, and 126 connected lines, and the density is 0.0689. When the threshold value is set to 4, the research keyword hotspots of domestic low carbon index systems are index system, low carbon economy, low carbon city, factor analysis, evaluation, low carbon development, carbon emission, low carbon industry, etc. The size performance of the nodes in the graph represents the frequency of this keyword, and the larger the node the higher the frequency. The largest node of the index system in Figure 1 indicates the highest frequency of its appearance. According to Figure 1, it can be intuitively found that the association between the index system and low-carbon pilot, peak emission, and eco-city is smaller, and the association with the low-carbon economy, low-carbon city, and low-carbon development is closer. And these research hotspots are also more closely related to each other.

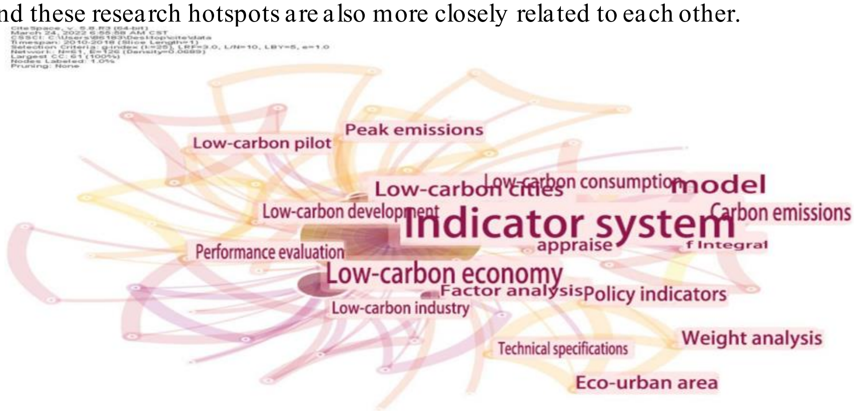

Fig. 1. Keyword co-occurrence mapping in domestic literature.

For keyword clustering of CiteSpace, the Modularity is represented by the value of Q, while the Mean Silhouette is represented by S. When the value of Q is greater than 0.3, the clustering structure of the map is significant; when the value of S is greater than 0.5, the clustering of the map is efficient and reasonable, and when the value of S is greater than 0.7, the map is convincing. From the basic information of Figure 2, the value of Q is 0.4818, greater than 0.3, which means that the clustered structure of the map is significant; the value of S is 0.852, greater than 0.7, which proves that the clustered map is convincing. In addition, from the perspective of clustering, the research of low-carbon indicators in China's literature can be mainly divided into the following clusters: (1) low-carbon economy (2) evaluation of levels (3) low-carbon cities (4) innovation system (5) model (6) carbon emission (7) technical indicators (8) sectors and authority. According to the cluster map, the clusters are closely related, among which clusters (1) and (3) are highly connected.

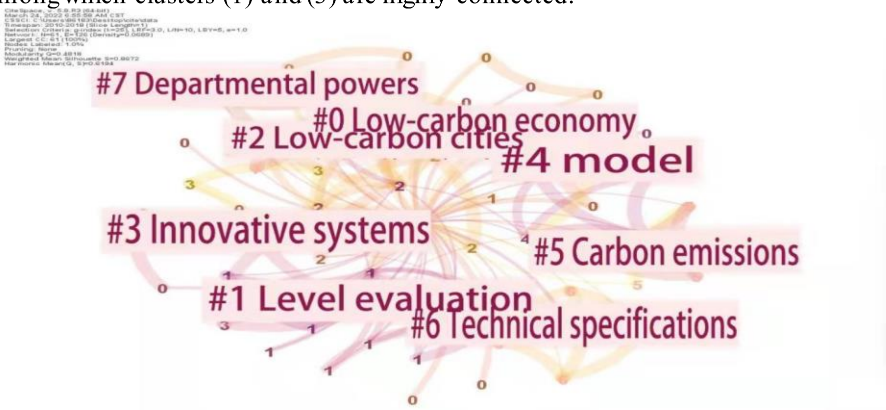

Fig. 2. Clustering mapping of keywords for domestic low-carbon indicator research.

Based on keyword co-occurrence and keyword clustering, a timeline chart can be created. Each label in the timeline diagram represents a category, and each member of each category is arranged sequentially by year. The timeline diagram generated by using CiteSpace technology can mainly analyze the research path of a certain field, which can make researchers understand more clearly the development line and direction of the research field, the active years of the branch topics of the research field, and thus make predictions on the trends.

From Figure 3, the nodes of the circular economy appear first, while the research path only lasted until 2010. The largest node is the index system and the research on the index system has continued until 2018 during which more indexes are studied including comprehensive evaluation, low-carbon development, and eco-cities. In addition, most of the research on low-carbon indicators focuses on urban areas, such as Jiangsu, Zhejiang, Shanghai, and Shenzhen. Moreover, empirical research wasn't carried out until 2015, but there was no continuous research. Between 2012 and 2017, the focus of research shifted from low-carbon industries to low-carbon transfomation and low-carbon agriculture.

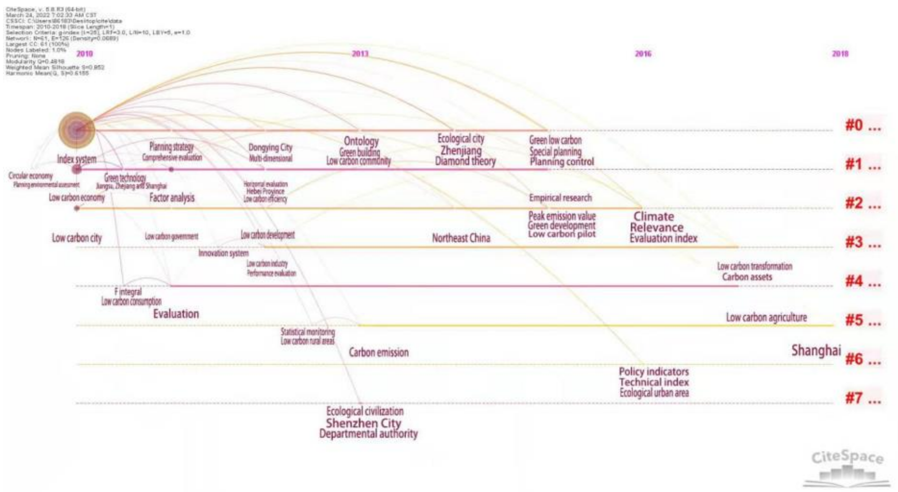

Fig. 3. Timeline diagram for research on low-carbon indicators in China

According to the map analysis, as little research has been conducted on low-carbon indicators in recent years, this paper aims to make up for this deficiency. Based on domestic scholars' research on several dimensions, this paper seeks to create indicators from such perspectives as economic level, urbanization degree, energy loss, and new energy technology. With factor analysis applied to the study of the change in low-carbon development of China from 2016 to 2020, thirteen indicators are analyzed: GDP, per capita income, the gross output of primary industry, secondary industry, and tertiary industry, percentage of urbanization, urban green area, total energy consumption, percentage of primary electricity and other energy sources, carbon emissions, sulfur dioxide emissions, the rate of sound treatment of domestic waste, and the comprehensive use of general industrial solid waste. Those indicators are set as X1, X2…, and X13 (Zhao, Liang, Shao, Zhao, 2021).

Table 1. Component score coefficient matrix

Name	ingredients				
	ingredientsi	ingredients2	ingredients 3	ingredients4	ingredients5
X1	-1.875	3.500	-0.250	1.906	-0.300
X2	0.250	-7.000	1.250	1.000	-0.349
X3	-1.250	2.750	1.625	3.375	-0.142
X4	1.500	-0.938	-0.313	-1.953	0.089
X5	1.250	-6.000	-1.750	-4.688	-0.005
X6	-0.438	-1.688	-2.531	-2.930	0.036
X7	2.250	-4.000	-0.250	-3.125	-0.701
X8	-0.313	4.000	-0.125	0.867	-0.030
X9	-2.750	5.000	0.500	2.563	0.242

X10	2.750	-6.000	1.500	0.719	0.160
X11	-0.938	0.625	-2.875	1.281	-0.347
X12	-0.250	7.000	3.500	4.688	0.617
X13	-2.500	3.500	-1.625	-0.938	0.094

Factor analysis is used to reduce the dimensionality of the indicators, which needs to be standardized because of the differences in each indicator. The results are derived by standardizing its raw data through SPSS software.

The consistency test of the data and indicators is performed by SPSS software. When the value of CR is less than 0.1, it can be determined that the distance of the judgment matrix on the total ordering of the hierarchy is satisfactory consistency.

Table 2. Summary of consistency test results

The largest feature root	CI	RI	CR	Consistency test results
13.000	0.000	1.560	0.000	Pass

Moreover, the weight of each indicator is calculated through the analytic hierarchy process, and the results of the corresponding weighting indicators illustrate which specific indicator has a greater impact on low-carbon, to offer suggestions on development.

Table 3. AHP analytic hierarchy results

item	Eigenvectors	Weight value	The maximum eigenvalue	CI
X1	1.115	8.579%		
X2	1.105	8.499%		
X3	1.031	7.931%		
X4	1.100	8.461%	13.000	0.000
X5	1.140	8.768%		
X6	0.985	7.579%		
X7	1.011	7.773%		
X8	0.987	7.589%		
X9	1.029	7.914%		
X10	0.945	7.273%		
X11	0.649	4.991%		
X12	0.943	7.250%		
X13	0.961	7.392%		

According to the factor load matrix obtained after its rotation, the factor analysis model of the index system can be derived from the effective factors: four effective factors are taken to analyze. Table 4 provides a reference for the direction of low-carbon development by analyzing China's achievements made in low-carbon development in recent years through model analysis.

Table 4. Comprehensive Evaluation for SPSS Analysis

Name	2016	2017	2018	2019	2020	weight
X1	0.3125	0.2196	0.2035	0.0916	0.0872	7.55%
X2	0.3134	0.2213	0.1940	0.0719	0.0583	7.51%
X3	0.2028	0.3407	0.4202	0.3869	0.3755	8.37%
X4	0.3382	0.1553	0.1398	0.0088	0.0216	6.98%
X5	0.3048	0.2388	0.2128	0.1145	0.1075	7.66%
X6	0.3131	0.1713	0.2460	0.3331	0.3461	7.45%
X7	0.2729	0.2490	0.3349	0.2476	0.2505	8.07%
X8	0.2880	0.2596	0.2627	0.1955	0.1894	7.91%
X9	0.2801	0.2741	0.2750	0.3567	0.3545	8.01%
X10	0.2246	0.3886	0.2536	0.5380	0.5318	8.05%
X11	0.2032	0.2680	0.4717	0.1838	0.1944	8.08%
X12	0.3316	0.1436	0.1982	0.3430	0.3388	7.19%
X13	0.1417	0.4778	0.1904	0.2120	0.2378	7.18%

According to the data analysis results, the impact of this dimension index of economic development on low-carbon development is relatively large, and the remaining two effective factors that affect the development of low-carbon also have a certain degree of impact on it, respectively. Combined with the previous literature indicators, the selected indicators are representative, which can reflect the actual problems to a certain extent However, in the selection of specific indicators, it is still necessary to carry out detailed processing work, some indicators are strong and weak in relation to various industries, as well as the proportion of weights in the overall analysis. According to the hierarchical analysis, it can also be seen that the influencing factors have a clear proportion of indicators and the scoring coefficient and these indicators are convincing, and representative.

3 Problems in Research on the Construction of Low-Carbon Index Systems

3.1 Construction of Low-carbon Index Systems Without Using Analysis Tools to Select Indicators

The national low-carbon index system is more concise and general than the local one (Table 7), and it is categorized into three aspects: economy, society, and ecology, which are reasonable and standard. By comparison, the first-level indicators of local systems are varied and unreasonable in eco-cities such as Xiamen, Guiyang, and Caofeidian. Take Xiamen as an example. Its eco-city index system covers 30 indicators that haven't been classified, and some indicators which are supposed to be second-tier in China's index system are regarded as the first-tier ones, which is not standard and consistent with the national indicators. Moreover, this means scientific analysis tools are needed to select indicators (Zhao, Gao, 2016).

Table 5. First-tier Indicators in China's Low-Carbon Urban-related Indicators System

Indicator System	Presenting Institution	Tier 1 Indicators	Fonnulation time
Ecological Modernization Index	Chinese Academy of Sciences	Ecological progiess. economic ecology, social ecology	
Low carbon city evaluation index system	China Institute of Standar dization and Institute of Enviionmental Standar dization	Economic. Social. Enviionmental	
Eco-city Index System	Cliiiia Urban Science Reseaich Association	Healthy ecological enviroimient, sustainable economic development, hannonious social progiess	
Ecological counties, ecological cities, ecological provinces constmction indicators (tidal diaft)	State Environmental Protection Adiniiiistiation	Economic development, ecological protection, social progress	2007
Xiamen Eco-city Index System		None (30 indicators in total, no specific gi adiiig)	
Guiyang Eco-city Index System		Eco-economy, eco-environiiient. liveliliood improvement, iiifiastinctme, eco-culture. clean and efficient	
Caofeidian Eco-city Indicator System	SWECO Sweden	Urban function, buildings and constiuction. tiansportation, energy, waste, water, landscape and public space	2009

3.2 Lack of Innovation in Research Tools and Methods of Index System

At present, studies have revolved around the construction of urban low-carbon index systems based on the DPSIR model, functional positioning, urban value, input and output, spatial pattern, climate influencing factors, and others. Existing low-carbon indicators have covered most aspects of assessing low-carbon cities, focusing on carbon emissions and their growth. In this paper, visual analysis through CiteSpace indicates that at present, the indicator of carbon absorption is lacking in most research, such as the proportion of residents' green travel. In addition, the carbon footprint of the inhabitants in a given area can also be used as an indicator foran in-depth study to assess low-carbon development in the area.

3.3 Analysis Tools to Select Indicators of Environmental System

Since 2010, China has launched three batches of 87 low-carbon pilot areas including Guangdong, Liaoning, Hubei, Shaanxi, Yunnan, Tianjin, Shenzhen, Chongqing, and Xiamen. Although cities in different regions have built low-carbon index systems, there is no need to formulate indicators in urban clusters such as the Yangtze River Delta, the Pearl River Delta, and Beijing-Tianjin-Hebei integrated cities. For example, in the Beijing-Tianjin-Hebei region, which is an important engine for China's economic development, the establishment of the system will become a stumbling block for economic development as the inconsistent environmental protection standards of the three areas make it difficult for the local economy to reap short-term benefits. Additionally, only some urban areas in some provinces have implemented a low-carbon index system. According to the data analysis of SPSS, economic development has a great impact on low-carbon development. In other words, the degree of urbanization also affects low-carbon development. Based on the literature indicators of the visualized selected areas of CiteSpace, the selected indicators are representative, which can reflect the problems in reality. However, indicators can be detailed to analyze the correlations with various industries, and the proportion of the weight. The hierarchical analysis reveals the proportion and scoring coefficients of the influence factors which are persuasive and representative.

4 Measures to Improve the Construction of Low-Carbon Index System

4.1 Strengthening Local Governments' Regulation of Low-Carbon Index System

First, local governments should explore the features of local economic development and formulate indicators based on their development. For example, northeast China, an old industrial base, has a large demand for petroleum, chemical, metallurgical, coal, thermal power, and other materials. Thus, large transport volumes greatly pollute the environment because the traditional extensive production mode plays a leading role. Therefore, local governments can consider the proportion of clean energy in primary energy consumption as a low-carbon economic indicator, and appropriately increase its proportion in the final data. Second, the local low-carbon economic indicators of the third or second tier should be classified into the first-tier ones proposed by the state to make them standardized. Third, the units and weights of each indicator should be considered from different dimensions to prevent misjudgment about the level of low-carbon economic development of a region or city.

Second, local governments should identify the most representative core indicators from the supply and demand sides. As the search for low-carbon indicators is a complicated process, more attention should be paid to solving carbon emissions, and the green and clean energy indicators help to explain the issue. Based on comprehensive analysis, adverse factors, directly and indirectly, affecting the carbon peaking and carbon neutrality goals are found to build low-carbon indicators and improve their credibility and validity.

4.2 Innovative Methods to Study New Indicators

It is important to optimize and upgrade the industrial structure. By 2021, the added value of China's primary industry reached 830.86 billion yuan, an increase of 7.1% over the same period last year; the added value of the secondary industry was 4509.04 billion yuan, up 8.2% over the same period last year while the added value of the tertiary industry recorded 609.68 billion yuan, a year-on-year increase of 8.2%. The figure indicates that the growth in the second and third industries hasn't been bigger than that of the primary industry during the same period. More efforts should be made to develop new industries, such as new energy and financial industries, so do green, circular economy and low-carbon agriculture. Second, new low-carbon indicators such as the proportion of new materials in urban buildings and people's low-carbon in urban transportation can be studied through various advanced computing software. Moreover, the prevalence of the low-carbon concept can also be assessed by integrating the urban residents' lifestyles related to carbon emissions into low-carbon index systems, such as frequency of traveling by public transportation and dietary habits.

4.3 Low-carbon Index System for City Clusters

According to the visual analysis of CiteSpace, data analysis of SPSS as well as the literature review, it can be seen that economic development has a large impact on the low-carbon economy. This also means that China needs to transform its economy by shifting from high-speed development to high-quality development in an attempt to better develop a low-carbon economy. The data analysis reveals that the influence factors also have a significant proportion in the level of urbanization, which means China must pay close attention to urbanization to reduce the impact of low-carbon development. By comparison, energy consumption and low-carbon technologies do not account for a large proportion of low-carbon development, which shows that low-carbon technologies should be encouraged. Meanwhile, new energy should be developed to save energy and reduce emissions and promote low-carbon development. Large-scale areas can be built to pursue low-carbon economic development and achieve low-carbon goals by developing a low-carbon economy across the region to reduce carbon emissions in city clusters. Effective low-carbon indicators can be established based on the conditions and characteristics of economic development in city clusters. And by analyzing the low-carbon economic development path of a certain region, the experience can be summarized and applied to more areas, thus promoting the low-carbon economic development of all cities in China.

5 Conclusions

At present, as China has devoted serious energy to a low-carbon economy, it is important to pursue the development of a low-carbon economy. This paper attempts to construct a low-carbon index system by analyzing the empirical research of CiteSpace and SPSS, which accelerate the development of a low-carbon economy. Thus, a reasonable low-carbon system is built according to the corresponding index system to propel the coordinated development between regions. With regard to low-carbon agriculture and ecological forestry which attract great attention, a new low-carbon index system must be developed based on scientific calculation and analysis methods to achieve better results in the low-carbon system. In addition, scientific analysis methods are used to continuously adjust carbon peaking and carbon neutrality goals, which means some low-carbon indicators of urban development will change dynamically because industry development and people's daily life affect the selection of low-carbon indicators. Only by timely considering the most relevant low-carbon indicators in the region can build the most effective low-carbon index system. Thanks to the analysis methods of CiteSpace and SPSS, low-carbon indicators can be efficiently selected, which helps to solve many problems of social development, such as the selection of impact factors in the development of agriculture and tourism. The author will continue to work on in-depth research on the software analysis methods to efficiently solve problems in life for scientific algorithm analysis to promote the orderly and sound development of society. At the same time, this paper provides a reference for the development of a low-carbon economy.

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