Evaluation on Low-Carbon Urban Construction Dominance Level in China

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Abstract:
Development of low-carbon economy is an important means to combat climate changes, and city, as the center of economic society, is the place mostly hit by carbon emission. Thus construction of low-carbon city is of great significance for development of low-carbon economy and industrial structure adjustment in China. Based on review of available domestic and foreign low-carbon city researches and definitions, a feasible low-carbon index system composed of 3 Ⅰ-level, 11 Ⅱ-level and 28 Ⅲ-level indexes from the perspectives of low-carbon economic development, low-carbon social civilization and low-carbon resource environment is established. A quantitative model for low-carbon city evaluation is established through ANP, for the purpose of systematic study of complex dependence and feedback relationship in the system, and comprehensive evaluation of low-carbon development level in 10 cities of China in 2011 is proposed.

Key words:
low-carbon city; index system; evaluation;

1. Introduction

The British Government proposed the concept of low carbon economy in the Energy White Paper [1], then urban low-carbon development came into the spotlight step by step. There are few studies on low-carbon city evaluation index system, which can be roughly divided into three categories: The first type is constructed evaluation index system of low-carbon cities from the three levels of economic, social and environmental [2]; consider the impact of resource consumption in the human social and economic activities of the city, to describe the low-carbon cities [3]; third category human production and life of the main departure from the four dimensions of the productivity of low-carbon, low-carbon consumption, low-carbon resources and low-carbon policy design low-carbon urban indicator system. These are a new attempt on the evaluation of low-carbon city. However, these studies focus on qualitative analysis on the economic level, some quantitative indicators data to the appropriate authorities for statistical data available [4].

So far, the problem of evaluation of measurement of low-carbon city is still a lack of uniform norms and generally accepted index system and evaluation method requires the joint efforts of many scholars. The analytic network process (ANP) is a relatively new and very effective method in modern performance evaluation and management decisions, which has been widely used in solving the forecasting, planning, effectiveness and conflict analysis. Evaluation in the city also has a small number of scholars have tried. GuoJie Zhao constructed index system of urban competitiveness based on ANP [5]; Dawei Zheng described the concept of generalized livable city [6]; Yanjun Huang compared the core competitiveness of Hangzhou and other cities with ANP[7]. Low-carbon city as the new content in the field of urban studies, and livable city, the concept of urban competitiveness has much in common with close ties, the index system is also a multilevel nature of the interconnected system. This article explores the ANP method applied to the evaluation of a low carbon city, and the model structure, application and other issues, in order to be to promote the popularization and application of low-carbon urban construction level measurement and ANP.

2. Construction of evaluation index system of low-carbon city

From the system point of view, low-carbon urban indicator system must take into account the collaborative development of the various elements of the demographic, social, economic and natural systems to achieve optimal overall function. Departure from the perspective of operability, basing on low-carbon economic development, low-carbon society civilized and low-carbon resources three dimensions, the evaluation index system of low-carbon is designed.

First, economic development is the basic requirement of a low carbon city. It can be reflected from the levels of economic efficiency, low carbon industry and the scale of urban development. Levels of economic efficiency represents a social and economic efficiency; low-carbon industry is mainly from the industrial structure to consider the high-class industrial structure often means lower carbon emissions, in general, the lower the energy dependence of the tertiary industry, the development state of environmental protection industry is directly related to the effectiveness of the urban governance of carbon

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emissions, high-tech industry on behalf of a knowledge-intensive, technology-intensive industries; the scale of urban development reflects the status of urban development, the factors must be considered when building a low carbon city mainly through the construction area and the urbanization rate to reflect[8].

Secondly, the degree of civilization of the city's low-carbon society, representing the city as a huge system of the effect of low-carbon economy, could be measured from the residents' quality of life, consumption patterns, and transportation system. Life quality of residents is to determine a level of urban construction of basic indicators; consumption is an important part of building a low carbon city, high-carbon consumption patterns will result in waste of resources and environmental pollution problems, serious impact on the construction of low-carbon cities; the transportation system is an important source of urban carbon emissions.

Third, the city's low-carbon resources and the environment, on behalf of certain technical conditions, to produce certain economic benefits, using fewer resources and producing less environmental pollution. It can be expressed through intensity of energy consumption, recycling of resources and pollutant emissions. Irreversible due to the scarcity of resources and energy, high-carbon and environmental pollution, urban construction must minimize the resource consumption of energy intensity, reduce pollutant emissions, and increase recycling of resources. Based on this, we constructed a low-carbon city evaluation index system, shown in Table 1.

3. Evaluation model of ANP-based low-carbon city

Measurement and evaluation of low-carbon cities is related to the multi-variable relations and multi-layer system. Although the index system of low-carbon cities shows a certain hierarchy between the levels, indicators, programs are not independent; there are complex relationships of the various dependencies and feedback. Compared to the AHP (Analytic Hierarchy Process) , ANP on account of the interdependence of the feedback between the levels and levels of internal elements, the credibility and accuracy of the evaluation result will be higher.

Table 1. Evaluation index system of low-carbon City

Ⅰ-level	Ⅱ-level	Ⅲ-level
Development of low-carbon economy （A）	Levels of economic efficiency（A1）	GDP growth rate (A11) Overall labor productivity (A12) Total assets of the contribution rate (A13)
	Low-carbon industries （A2）	Tertiary industry proportion of GDP (A21) Proportion of environmental protection industry (A22) High-tech industries accounted for the proportion of industrial output value (A23)
	Urban construction scale （A3）	Built-up area acreage(A31) Urbanization rate of A32 The construction of fixed assets investment (A33)
Low-carbon society civilization (B)	Quality of life B1	Per capita disposable income (B11) Engel coefficient (B12) Per capita housing area (B13)
	Consumption patterns B2	Per capita electricity consumption (B21) Per capita liquefied petroleum gas using (B22) Number of private cars (B23)
	Transportation system B3	Per capita road area (B31) The bus number per 10000 people (B32) Grade highway mileage number (B33)
Low-carbon resources and the environment (C)	Energy consumption intensity C1	Industrial energy productivity (C11) Per capita industrial water use (C12) Per unit of GDP energy consumption (C13)
	Resources cyclic use C2	Living garbage treatment rate (C21) Industrial solid waste comprehensive utilization rate (C22) Wastewater recycling utilization rate (C23)
	Pollutant emissions C3	Industrial SO_2 emissions (C31) Industrial wastewater discharge amount (C32) COD discharge amount (C33)

3.1. Network structure based on low-carbon city of the ANP model assessment index

Building from the low-carbon urban indicator system, the 3Ⅰ-level indicators, such as the low-carbon economy (A), low-carbon society civilized (B), and low-carbon resources and environment (C), are independent of each other. The 3 Ⅰ-level indicators as the model evaluation criteria, with the goal of low-carbon urban construction level constitute control layer of the ANP model. ANP structure model of low-carbon urban construction level is constructed based on analysis of the dependencies between the various indicators.

3.2. Judgment matrix and consistency test

ANP judgment matrix is pair-wise comparison matrix, built by taking affecting factors pair-wise comparison with the 9 scales method. Due to ANP comparison between elements may not be independent, but there is a feedback relationship between the index set of elements internal or external dependencies as well as indicators and programs. This article introduced the concept of indirect dominance, which is, given a criterion to compare two elements in the guidelines under the third element. Control layer in the evaluation system in the low carbon city-level indicators set of elements A, B, C, the network layer by the two indicators of elements of group A1, A2, ..., C3, and two indicators of the three indicators of A11, A12, ..., C33. Control layer in an index as a criterion for the second criteria to all three indicators, three indicators of effect size indicators for indirect advantage, is constructed for each standard and all three indicators of the judgment matrix. Eigenvectors normalized judgment matrix calculation by the eigenvalue method, while the maximum characteristic root, denoted at λmax. Judgment matrix consistency test: When the random consistency ratio CR = CI / RI <0.1, that the judgment matrix has satisfied consistency, otherwise re-adjust the judgment matrix element values.

3.3. The calculation of matrix, the weighted super matrix and extreme ultra-matrix

Super matrix sub-matrix composed by the judgment matrix between each decision level, re-sort the rights of each column are based on an element as a criterion. Low-carbon city evaluation system composed of 1 target, 3Ⅰ-level, 9Ⅱ-level, 27 Ⅲ-level, 10 program elements, so super matrix W is a 49×49 matrix. For simplicity, the ultra matrix W conducted owned by a processing matrix P, will exceed the matrix W and the matrix P by multiplying the weighted super matrix $\bar{W}$, each column sum is 1. The weighting matrix reflects the influence degree between the groups, such as A1 and B1. Then weighted super matrix $\bar{W}$ normalized through the process of iterative, gradually stabilized, the calculated limit super-matrix W'. In the appropriate criteria, the limit of the relative priority of each indicator was obtained, which is sort of the importance of each indicator.

4. Empirical Models

4.1. Data sources

Based on the above index system and model, the 10 cities in China low-carbon level of the building were evaluated. Quantitative indicators of data are derived from the China Statistical Yearbook (2011) as well as various cities in the 2011 National Economic and Social Development Statistics Bulletin, part of the data being processed. The evaluation model of a secondary index weights related to or inter-city relationship between the indexes, both by letter, telephone, etc., the relevant experts in the field of questionnaire score after statistical processing obtained. In addition, the Engel coefficient, energy consumption per unit of GDP and other negative indicators were positive treatment.

4.2. Evaluation Results

In the Super Decisions [9], ANP software computing, input all levels of evaluation index system of low-carbon city index composed of the set of elements and internal elements units, to establish each element, the indicators inter-dependency, domination, feedback and other complex relationships, get a low carbon city construction level evaluation index system of network-level diagram. Experts to establish the relationship between matrix inputs to the software at the same time as a measure matrix can be passed to the consistency test. The Super Decisions software in the input data can be calculated by the un-weighted super-matrix, weighted super matrix and limit super-matrix. Due to limited space, only the listed cities low carbon construction level evaluation results are shown in Table 2.

Table 2. Evaluation results of low-carbon urban construction dominance level

Cities	Dominance level	Cities	Dominance level
Beijing	1.000000	Tianjin	0.771659
Shanghai	0.891878	Nanjing	0.759727
Shenzhen	0.872261	Xi'an	0.698746
Guangzhou	0.812286	Chongqing	0.659892
Hangzhou	0.809445	Shenyang	0.646704

4.3. Analysis

Seen from Table 2, the low carbon level of the building of the 10 sample cities in descending order are Beijing, Shanghai, Shenzhen, Guangzhou, Hangzhou, Tianjin, Nanjing, Xi'an, Chongqing, and Shenyang. For comparison purposes, the comprehensive advantages of the evaluation results of the various cities, these cities will be divided into three categories: the top level of low-carbon urban construction in Beijing, Shanghai, Shenzhen, indicating that the relative strength of these cities low carbon level of the building, its classified as class Ⅰ city; Guangzhou, Hangzhou, Tianjin, Nanjing, low-carbon urban construction level at the middle level, classified as class Ⅱ city; Xi'an, Chongqing, Shenyang, low-carbon level of the building is relatively weak, normalized for class Ⅲ city.

5. Conclusions

The construction of low-carbon cities is essential for the development of low-carbon economy. Operable evaluation of a low carbon city is also a lack of quantitative research. Have sex on the basis of full consideration of the data from the low-carbon economic development, low-carbon society civilization, three aspects of low-carbon resources and the environment to build a strong operational low-carbon urban indicator system and ANP Methods in the city this complex social system, the gradual decomposition of the complex low-carbon city to both the connections and differences between different levels, taking fully into account the indicator element set, the set of dependencies of the program elements and program elements set the indicator element set of feedback relations, to overcome the deficiencies of the traditional AHP, amendments to the indicators, and evaluation results closer to the true state of the urban low-carbon building. On this basis, the low carbon level of the building in 10 Chinese cities in 2011 were evaluated from the results of this method is with a strong practicality.

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