Construction of Low Carbon Environment Evaluation Index System Based on AHP

Libin Xie, Heyan Yuan
Fuzhou University of International Studies and Trade, Fuzhou 350202, Fujian, China

Abstract. Low-carbon auditing plays an important role in the development of low-carbon economy as an important means of monitoring energy conservation and emission reduction. Constructing a low-carbon audit evaluation index system will help achieve the goal of low-carbon audit and promote the development of low-carbon audit. This paper uses AHP (Analytic Hierarchy Process) to determine key impact indicators and build a low carbon audit evaluation model.

1. Introduction
As one of the important contents of environmental audit, low-carbon audit is a monitoring method for building a low-carbon economic environment and plays an important role in energy conservation and emission reduction. Different from traditional auditing, low-carbon auditing not only audits financial affairs, but also audits low-carbon performance, fulfillment of responsibility for ecological civilization construction and social benefits. Conducting low-carbon audits can better evaluate and supervise low-carbon environments, promote energy conservation and emission reduction, and help society to build a low-carbon economy and provide a good living environment for human society. As a key evaluation criterion for low-carbon audit work, the low-carbon audit evaluation index system is conducive to improving China's low-carbon audit system, and also helps to find out the shortcomings of China's development and make targeted improvements.

2. China's low carbon audit evaluation index selection

2.1. Method selection
The Analytic Hierarchy Process (AHP) proposed by T.L.Saaty can quantify the indicators that cannot be quantified by general methods, and help researchers solve the problems of both qualitative and quantitative indicators. Therefore, this paper will build a low-carbon audit evaluation system in China by means of analytic hierarchy process.

2.2. Low carbon audit evaluation index selection principle

2.2.1. Systematic principles. The low-carbon audit evaluation index system is a whole, and each indicator should not only be compatible with other indicators, but also have a hierarchy relative to other indicators. Adaptation of indicators is an important aspect of requiring the indicators to have their own focus while taking into account the entire indicator system. The indicators and indicators should be interconnected and coordinated. The stratification of indicators refers to the degree of comparison
between indicators and indicators, used to indicate the relationship between indicators, and different indicators exist at different levels.

2.2.2. Policy related principles. The development of a low-carbon economy must have policy support. Similarly, low-carbon audit work should also have corresponding policies. Low-carbon auditing is an audit of the problems that occur in the process of developing a low-carbon economy. The auditing process and the selection of auditing indicators cannot be decided at will. The appropriate evaluation indicators should be selected after comprehensive consideration based on relevant policies issued by the government.

2.2.3. Target principle. Targeted means that the choice of indicators is to serve an overall goal, and the corresponding audit work is carried out after the final goal is clarified. The ultimate goal of constructing China's low carbon audit evaluation index system is to supervise carbon emissions, improve China's energy utilization structure, and serve China's development of low carbon economy. Only a clear purpose can help to choose the right indicators.

2.2.4. Specificity principle. When selecting low-carbon audit evaluation indicators, it is necessary to pay attention to the fact that the selected indicators are related to the evaluation target and closely related to each specific target of the evaluation object. In other words, it is necessary to pay attention to the specificity and pertinence of the selected evaluation indicators. At the same time, the selection of indicators should avoid fuzziness and abstraction as far as possible. It should be clear and clear so that users can quickly understand the designer's intentions.

2.3. Selection of China's low carbon audit evaluation indicators

2.3.1. Selection of indicators. Compared with traditional audit, low-carbon audit is more complex and involves many and non-centralized indicators. This paper chooses four first-level indicators, namely, low-carbon economic benefits, low-carbon policy, low-carbon technology and low-carbon environment, to assist in the construction of China's low carbon audit evaluation index system. Firstly, the research objective of this paper is the evaluation index of low-carbon economic audit in China. Therefore, based on the current situation of low-carbon economic development in China, the secondary value of low-carbon economic benefits selected after comprehensive research is marked as: the proportion of secondary industry, the per capita gross product, the Real GDP per capita, and the growth of GDP’s speed. Secondly, most of the low-carbon policies are guided by the government. According to the policy-oriented principle, the secondary indicators selected include: government carbon capital investment, carbon capital availability rate, and citizen's awareness of environmental protection. Thirdly, the improvement of low-carbon technology can improve China's carbon emissions. At present, China's air purification enterprises have not been fully popularized, and the technology of carbon conversion has not yet been perfected. In order to assess whether the energy consumption and resources of the audited objects have been rationally utilized. The following secondary indicators are selected under the first-level indicators of carbon technology: energy consumption, carbon conversion rate, and resource utilization rate. Finally, low-carbon auditing is an important part of environmental auditing. Only by combining China's environmental monitoring data in recent years can we effectively improve our low-carbon environmental audit work. Therefore, with reference to national environmental related indicators, the secondary indicators selected under the low-carbon environment primary indicators are: average carbon dioxide concentration, average concentration of sulfur dioxide, average concentration of nitrogen dioxide, and inhalable particulate matter.

2.3.2. Explanation of indicators

(1) Low-carbon economic benefit index: Select per capita GDP as an indicator of economic development, which is more objective and fair. If a region's per capita GDP is high, then it can be judged
that the region is at a level of economic development. GDP growth rate refers to the gross national product of a country or region compared to the previous year’s growth rate, this indicator may reflect how fast the pace of development in certain areas; the development of the secondary industry a greater impact on the environment, Carbon emissions are also relatively large, and the setting of this indicator can detect the contribution of the secondary industry in developing a low-carbon economy.

(2) Low-carbon policy: The government's carbon capital investment is led by the government. It specializes in carbon credit trading, energy conservation and emission reduction, and special funds for reducing and controlling greenhouse gases. It is part of the low-carbon policy; the carbon capital availability rate refers to the original government. The total amount of carbon funds planned, the actual use rate in the actual carbon trading market; the popularity of citizens' environmental awareness is mainly based on the promulgation of various government policies, what kind of propaganda methods are chosen by various organizations, and what content is promoted with citizens' environmental awareness related.

(3) Low-carbon technology: Energy consumption is the most direct indicator for testing low-carbon technologies; carbon conversion rate is to re-process the carbonaceous materials emitted during the production of products, and convert some of the carbon into no pollution to the environment or the ratio of less polluting emissions; resource utilization refers to the utilization of various resources in China, which enables all domestic resources to be “utilized”, to improve low-carbon technologies and improve utilization.

(4) Low-carbon environment: Carbon dioxide is the main component of greenhouse gases. When more than 80% of the global air is carbon dioxide, it may cause serious environmental degradation. The concentration of sulfur dioxide in the air is too high, and acid rain will not only corrode buildings, acid-soiled soils reduce the yield of agricultural plants; nitrogen dioxide can become toxic gases at high temperatures, endangering people's health; in addition, nitrogen dioxide and water in the air produce chemical reactions that produce acid rain; Particulate matter is mainly dust in the air, which is PM2.5.

3. Based on AHP to build a low-carbon audit evaluation index system

3.1. Building a judgment matrix

The judgment matrix is the basis for judging the importance of each element. The degree of importance between two indicators in an indicator layer is usually expressed by a ij (the i element and the j factor in the same indicator layer). In this paper, the AHP method combined with the Delphi method are used to assist the construction of the evaluation system. In order to increase the objectivity of the data, this paper adopts the method of consulting professionals to select 40 experts who are concerned about low-carbon auditing in the four fields of college teachers, government departments, enterprises and low-carbon industries to make low-carbon audit evaluation indicators; At the same time, through the Delphi method, the experts’ opinions were analyzed in multiple rounds. Taking the first-level indicator as an example, the judgment matrix constructed is as follows:

| A   | B₁ | B₂       | B₃ | B₄ |
|-----|----|----------|----|----|
| B₁  | 1  | 3        | 2  | 2  |
| B₂  | 1/3| 1        | 1/3| 1/2|
| B₃  | 1/2| 3        | 1  | 2  |
| B₄  | 1/2| 2        | 1/2| 1  |

Due to space limitations, the judgment matrix of each secondary indicator is not listed one by one.

3.2. Determine indicator weights

There are various methods for determining the specific weight of indicators. In this paper, the geometric mean method is mainly used. First, the vector set $W^* = (W_1^*, W_2^*, W_3^*, W_4^*)$ T is calculated,
and then the vector $W^*$ is calculated again. The eigenvectors $W=(W_1, W_2, W_3, W_4)$ of the matrix are calculated by calculation, that is, the required weight vector; the maximum eigenvalue of the matrix is calculated after the matrix weight vector is calculated. According to the software yaahp, the matrix weight values are as shown in Table 2 below.

**Table 2. Evaluation target A - First-level indicator B judgment matrix weight value**

| A   | B1   | B2   | B3   | B4   | Wi     |
|-----|------|------|------|------|--------|
| B1  | 1    | 3    | 2    | 2    | 0.4179 |
| B2  | 1/3  | 1    | 1/3  | 1/2  | 0.1090 |
| B3  | 1/2  | 3    | 1    | 2    | 0.2485 |
| B4  | 1/2  | 2    | 1/2  | 1    | 0.2245 |

According to the above calculation, the weight set of the first-level indicator is $W_A=(0.4179, 0.1090, 0.2485, 0.2245)^T$, and the maximum eigenvalue $\lambda_{\text{max}} = 4.0457$ of the matrix is calculated. Similarly, the weight sets for calculating the remaining secondary indicators are:

- $W_{B_1} = (0.5278, 0.3325, 0.1396)^T$, wherein the maximum root $[\lambda \text{ max}]_{\text{max1}} = 3.0536$
- $W_{B_2} = (0.5936, 0.2493, 0.1571)^T$, the largest eigenvalue $\lambda_{\text{max2}} = 3.0536$
- $W_{B_3} = (0.4934, 0.3108, 0.1958)^T$, the largest eigenvalue $\lambda_{\text{max3}} = 3.0536$
- $W_{B_4} = (0.4369, 0.3089, 0.0930, 0.1612)^T$, the largest eigenvalue $\lambda_{\text{max4}} = 4.2148$

### 3.3. Indicator consistency test

The consistency test can avoid subjective inconsistencies, and the consistency check of the matrix is generally expressed by the random consistency ratio CR (Figure 1).

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1} \quad \text{CR} = \frac{CI}{RI}$$

![Figure 1. Formula for calculating matrix consistency](image)

Taking the evaluation target A - first-level indicator B judgment matrix as an example, the judgment matrix is calculated by the formula:

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1} = \frac{4.0457 - 4}{4 - 1} = 0.0152$$

According to the average random consistency indicator RI reference table given by Saaty (Table 3),

**Table 3. Average Random Consistency Indicator RI**

| Matrix order | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|
| $RI$         | 0.00| 0.00| 0.52| 0.89| 1.12| 1.26| 1.36| 1.41|

When $n=4$, the RI is 0.89:

$$CR = \frac{CI}{RI} = \frac{0.0152}{0.89} = 0.0171 < 0.1$$

Pass the consistency test. Similarly, the consistency index of the second-level indicator judgment matrix is calculated as $\text{CR } 1 = 0.0516 < 0.1$, $\text{CR } 2 = 0.0516 < 0.1$, $\text{CR } 3 = 0.0516 < 0.1$, and $\text{CR } 4 = 0.0805 < 0.1$. The CR values of the above indicators are all below 0.1, which meets the consistency
requirements, indicating that the low carbon audit evaluation index system constructed in this paper meets the practical requirements. Finally, the final weights of each indicator are calculated as shown in Table 4.

| Target (A) | Primary indicator (W_B) | Secondary indicator (W_Ci) | Total weight (W_B*W_Ci) |
|------------|-------------------------|---------------------------|------------------------|
|            | B_1 (0.4179)            | C_11 (0.2206)             | 0.0922                 |
|            |                         | C_12 (0.1390)             | 0.0581                 |
|            |                         | C_13 (0.0584)             | 0.0244                 |
|            | B_2 (0.1090)            | C_21 (0.0647)             | 0.0071                 |
|            |                         | C_22 (0.0272)             | 0.0030                 |
|            |                         | C_23 (0.0171)             | 0.0019                 |
|            | B_3 (0.2485)            | C_31 (0.1226)             | 0.0305                 |
|            |                         | C_32 (0.0772)             | 0.0192                 |
|            |                         | C_33 (0.0487)             | 0.0121                 |
| China's low |                         | C_41 (0.0981)             | 0.0220                 |
| carbon audit |                         | C_42 (0.0694)             | 0.0156                 |
| economic    |                         | C_43 (0.0209)             | 0.0047                 |
| evaluation  |                         | C_44 (0.0362)             | 0.0081                 |
| index       |                         |                           |                       |

Based on the above calculation results, with reference to the weights of the selected indicators in this paper, we will formulate China’s low carbon audit evaluation index system to better promote the implementation of China’s low carbon audit work, and help China to develop a low carbon economy while taking into account the low carbon environment.

4. Conclusion

Economy, policy, technology and environment are the cornerstones of economic development. The development of any country or region should not seek the illusion of "aerial castle". The development of low-carbon audit should be down-to-earth from all aspects. The paper constructs an audit evaluation model from a low-carbon perspective. In the follow-up study, it will conduct empirical research based on actual cases and continue to explore the possible and specific measures for the continuous optimization of the audit indicator system under the low-carbon concept.

References

[1] Jianhui G, Yaguai Y. The Evaluation Index System Construction of Low-Carbon Audit [C]. Proceedings of the 2012 3rd International Conference on E-Business and E-Government - Volume 02. IEEE Computer Society, 2012.
[2] Jinguo X, Yanxia W. The Quantitative Evaluation Method of Low-carbon Economy Auditing [J]. Energy Procedia, 2011, 5 (none): 1014-1018.
[3] Tang Q. Institutional Influence, Transition Management and the Demand for Carbon Auditing: The Chinese Experience [J]. Australian Accounting Review, 2017 (3).
[4] Saaty T L. Analytic Hierarchy Process [M]. Encyclopedia of Biostatistics. John Wiley & Sons, Ltd, 2005.
[5] Zanardo R P, Siluk J C M, Fernando D S S, et al. Energy audit model based on a performance evaluation system [J]. Energy, 2018, 154: 544-552.
[6] Ji L, Cui M X. Research on the Environmental Performance Audit Evaluation Index System Construction of Country Government in China [J]. Advanced Materials Research, 2014, 962-965: 2133-2136.