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Sustainable development of coal cities in Heilongjiang province based on AHP method

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ABSTRACT

The sustainable development of coal mining cities in Heilongjiang province has important effect on the economic stability and development of Heilongjiang, Northeast China, and China at large. To further the sustainable development evaluation system of coal mining cities in Heilongjiang province, based on the analytic hierarchy process (AHP) method combined with operational and scientific principles using Saaty's 1–9 scale method to construct the judgment matrix from five aspects, such as economic development and environmental quality, this paper establishes the comprehensive evaluation index system of sustainable development of coal mining cities in Heilongjiang province, including comprehensive index of industrial economic benefits and the contribution rate of science and technology. In addition, using fuzzy comprehensive evaluation method, a comprehensive evaluation is made on the indices of the four major coal mining cities of Heilongjiang. The result shows that the coal mining cities are not better than Datong of Shanxi province in many indices. The economic development and environment quality are the most important indices of the targeted layer influencing the sustainable development of coal mining cities of Heilongjiang, and their index weights are 0.4358 and 0.2844, respectively. These two indices including comprehensive index of industrial economic benefit and the ratio of environmental protection investment to GDP are the key elements influencing the two aspects.

1. Introduction

China's national 12th 5-year plan proposes to revive the China northeastern old industrial bases, and promotes the transformation development in resource-exhausted areas. Heilongjiang province is enriched with coal resource. The four major coal mining cities of Hegang, Jixi, Shuangyashan, and Qitaihe have their own development advantages. They have rich coal resource, whose reserves account for 90% above of Heilongjiang's mineral resources. However, restricted by the traditional development pattern, the problems of low coal resource utilization rate and imbalanced industrial structure of Heilongjiang province are hindering the development process [1–3].

Many coal mining cities in the world have proposed sustainable development plans. But, to what sustainable extent do coal mining cities develop, and what are the outcomes? All those sustainable development index issues of resource-based cities are discussed by some Chinese scholars. However, how to evaluate sustainable development of coal mining cities is still a hot research issue [4–5]. Foreign literature on sustainable development of coal mining cities focus on the factors of organization and corporate governance, while domestic interests fall in transformation and continuous establishment of industries. This paper makes evaluation on the major coal mining cities of Heilongjiang based on sustainable development evaluation index system of coal mining cities.

2. AHP principle and steps

2.1. Hierarchical structure

Based on the problems analyses, the complex problems are decomposed into component elements, whose attributes are subdivided into several groups, which form the hierarchical structure [2,6].

2.2. Generate judgment matrix

Two elements were selected each time, and a_{ij} indicate the ratio of comparative importance. All the comparison results are indicated by A, which is the judgment matrix. The matrix is given by experts well experienced with the problems [7].

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$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & & & \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

2.3. Test evaluation of judgment matrix

2.3.1. Element quantification

In order to quantify the elements of judgment matrix, Saaty's 1–9 scale method was employed in our study.

2.3.2. Consistency test

In Saaty scale method, numbers 1–9 are used to scale the impact level of 2 indices on one element, but some scale reciprocals are circulating decimals and rounding off may destroy the condition, and the consistency condition for judgment matrix, i.e., non-zero characteristic value $\varepsilon_{\max}=m$. Furthermore, when the importance of elements i, j and k are close to each other, experts compare the indices, maybe by bringing the outstanding problem that j is more important than i, i more than k, and then k more than j [8]. This may happen when many indices are used. Therefore, the judgment matrixes derived from comparison of two elements may sometimes be inconsistent. So, the consistency test on judgment matrix is necessary. The consistency ratio CR is usually employed in AHP method, as shown in Eq. (2).

$$C_{ij}=1/C_{ji} \quad \varepsilon_{\max}=\frac{1}{m}\sum_{i=1}^{m}\frac{(A\delta)_i}{\delta_i} \tag{2}$$

$$CR=CI/RI \quad CI=\frac{\varepsilon_{\max}-m}{m-1} \tag{3}$$

where CI is the consistency index, m the judgment matrix order, $\varepsilon_{\max}$ the maximum characteristic value of judgment matrix, and RI the correction freedom index, as shown in Table 1.

When CR increases, the matrix consistency decrease, and vice versa. When $\varepsilon_{\max}=n$, $CR=0$, the matrix is in complete consistency; usually when $CR\leqslant 0.1$, the matrix is qualified by consistency test, otherwise, comparison should be made once more, till a final qualified test is obtained.

2.3.3. Determine comparative weights of elements

If the judgment matrix is a consistent matrix, then solving the characteristic value $A\delta=n\delta$, we can obtain $\delta=(\delta_1,\delta_2,\ldots,\delta_n)'$, and its normalized results are the weights of elements. Many scholars have proposed other weight calculation methods, such as upper triangular element method and OLS, and these methods have their own leading edges in different conditions.

3. Principles to generate the index system

3.1. Operability and science

The evaluation index system should comprehensively reflect the strategic objectives of the sustainable development of coal mining cities, the element sustainability of environmental quality, resource protection and utilization. The index selection should be based on the systematic research of sustainable development and full understanding of coal cities [9–10].

Table 1
Correction freedom indices.

Dimension	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

3.2. Static pertinence and dynamic induction

The sustainable development of coal mining cities is either a process or an objective. Therefore, the index system should fully reflect cyclic economic development status quo, and system dynamic change of coal mining cities [11–13].

3.3. Representativity and comprehensivity

The index system should comprehensively reflect the main characteristics in the aspects of ecological environment, economy, and society of the coal mining cities. In addition, index selection should be representative and typical, removing the synonymous and repeating indices [14].

3.4. Integrity and relativity

The elements of sustainable development systems of the coal mining cities are interactive and form an organic integrity, and the inter-collaborative and interactive indices are selected to fully reflect the overall development situation of coal cities [15].

4. Generate sustainable development evaluation index system of coal cities in Heilongjiang province

4.1. Framework of index system

The index system is based on AHP method. First, identify the main elements influencing sustainable development of the coal mining cities, and then determine the sub-indices reflecting the main elements, on the analogy of this rule, decomposing till to the single evaluation index in the bottom layer. A sustainable development system of resource-type cities is a gradual coupling operational system and consisting of 3-layer hierarchical structure.

(1) Strategic layer A. It fully reflects sustainable development trend and effects of the coal mining cities in Heilongjiang province, and the overall development objectives of the coal mining cities.
(2) System layer B. The overall development objectives of the coal mining cities are decomposed to economic development system, environmental quality system, resource state system, social harmony system, and government administration capability system.
(3) Index layer C. They are the specific elements fully reflecting the activities of the coal mining cities, 30 indices in total.

4.2. Generate hierarchical structure model

Table 2 illustrates the 30 indices of 5 classes in the generate AHP hierarchical structural model.

5. Empirical study of sustainable development evaluation of coal cities in Heilongjiang province

Using AHP method, determined the weights of system layers, and then determined the weights of specific indices. Weights of all indices are shown in Table 3.

The index weights were determined based on AHP method, and then a comprehensive evaluation was made using fuzzy comprehensive judgment method. This method refers to the comprehensive decision-making method to some aims on some items concerning all impacting factors in the fuzzy environment [3–4].

When the fuzzy comprehensive judgment model is used, membership function employs Cauchy distribution, i.e.,