Priority-sequence of mineral resources' development and utilization based on grey relational analysis method

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Generally, the sequence decision of the development and utilization of Chinese mineral resources is based on national and provincial overall plan of the mineral resources. Such plan usually cannot reflect the relative size of the suitability of the development and utilization of mineral resources. To solve the problem, the paper has selected the gift condition, the market condition, the technological condition, socio-economic condition and environmental condition as the starting-points to analyze the influential factors of the priority-sequence of mineral resources' development and utilization. The above 5 conditions are further specified into 9 evaluative indicators to establish an evaluation indicator system. At last, we propose a decision model of the priority sequence based on grey relational analysis method, and figure out the observation objects by the suitability index of development. Finally, the mineral resources of a certain province in China were analyzed as an example. The calculation results indicate that silver (2.0057), coal (1.9955), zinc (1.9442), cement limestone (1.9077), solvent limestone (1.5624) and other minerals in the province are suitable for development and utilization.

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1. Introduction

When making plans for the protection and development of mineral resources, the Chinese government departments divide the mineral resources of the planning area into three kinds by the mineral species: exploitation-encouraged mine, exploitation-restricted mine and exploitation-prohibited mine [1]. The division is based on the relevant policies and regulations, the supply-demand situations of mineral resources and the environmental impact degree of the development and utilization. This sequential relationship is shown in Fig. 1.

Generally, the decision-making process of the development and utilization of Chinese mineral resources is as follows: firstly, the Ministry of Land and Resources makes a national overall plan of the national-level mineral resources; Subsequently, the provincial departments of Land and Resources set up a provincial overall plan in accordance with the national overall plan; finally, the Land and Resources Bureau of all the municipalities or counties carries out the national and provincial overall plan of the mineral resources.

From the national overall plan of the national-level mineral resources to the provincial overall plan, the mineral resources of the planning area are divided into three kinds by the mineral spe-

cies. This classification scheme is feasible in principle, but it does not reflect the relative size of suitability of mineral resources' development and utilization. Thus, development and utilization of several mineral resources cannot be taken into account, and minerals must be sorted in order to select the optimal one. This three-category classification is often a lack of convincing when the above happens.

2. Choice of method of sequence decisions

Scholars have tried to put forward a variety of methods for sequence decision of mineral resources' development and utilization, and they want to find a more scientific and reasonable way to address the issue. These methods and countermeasures are summed up as follows: considering the factors effecting suitability of mineral resources' development and utilization, trying to decompose and quantify the various factors as far as possible, assessing the suitability of mineral resources' development and utilization via the sophisticated mathematical statistical analysis model. Those methods include analytic hierarchy process (AHP), fuzzy comprehensive evaluation method, AHP and fuzzy comprehensive evaluation method in combination, grey relational analysis [2].

Limited by the research degree, the determination of priority-sequence of mineral resources' development and utilization based on AHP and fuzzy comprehensive evaluation still has a feature of

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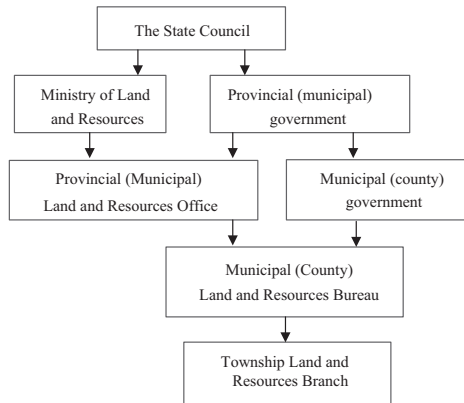
Fig. 1. Decision Structure of mineral resources development and utilization.

qualitative analysis. Simultaneously, there are strict requirements for number and relevance of the factors.

As one of the analysis methods of grey system theory, grey relational analysis is used to determine the relational degree of the factors according to the similarity degree of the geometry of the various factors changing curve. To use grey relational analysis, it only needs the sample capacity of 3 or more. And grey relational analysis is also applicable to the irregular data. Furthermore, by using grey relational analysis, there will not appear the inconsistent between the quantitative results and qualitative analysis [3]. The application of grey relational analysis in sequence decision-making on the development and utilization of mineral resources can play all the advantages of its own.

3. Establishment of the priority-sequence model

To solve the problem that the national and provincial overall plans of the mineral resources cannot reflect the relative size of the suitability of the development and utilization of mineral resources, we establish the sequence of the protection and exploitation of the mineral resources based on the grey relational analysis principle.

3.1. Analysis of the factors affecting the priority sequence

There are many factors that affect the mineral exploitation order and five of them will be analyzed in this article:

(1) Natural characteristics of mineral resources

The natural characteristics of mineral resources are the most basic factor in affecting the degree of difficulty in the development and utilization of mineral resources [4]. Because of different development conditions, the investment in the exploitation of the same amount of resources might be greatly different [5].

(2) Market conditions

The market conditions of mineral resources include two aspects which are supply and demand. The resource prices that are decided by the relationship of supply and demand will ultimately affect the development and utilization decisions [6].

(3) Technical conditions

Technical conditions are external conditions which affect the degree of difficulty in the development and utilization of mineral

resources, including the exploration, exploitation, mining and processing levels, matching degree of the development and utilization of mineral resources, etc.

(4) Social and economic benefits

Social and economic benefits of the development and utilization of mineral resources determine whether the kinds of mineral resources worth developing, and the priority sequence of development. Contribution to GDP and capacity to promote the employment are the most two important aspects of socio-economic benefits.

(5) Environment protection conditions

The development of mineral resources and the environmental conditions are dependent on each other. On one hand, the severe natural environment may hinder the development and utilization of resources, on the other hand, the degree of exploitation of resources will influence the environment.

3.2. Establishment of the evaluation system of priority-sequence

In order to analyze the suitability and compare the priority of the development and utilization of mineral resources, we should establish the evaluation system of priority-sequence on the development and utilization of mineral resources [7]. The development and utilization of mineral resources are affected by the above 5 factors. Therefore, the establishment of the evaluation system of priority-sequence on the development and utilization of mineral resources can focus on these 5 factors. But, these 5 factors' descriptions of the development and utilization of mineral resources are too vague and broad. To solve the problem, several representative indicators will be selected for each factor. There are totally 9 indicators, which reflects the priority-sequence of the development and utilization of mineral resource [8]. The evaluation indicator system of priority-sequence on the development and utilization of mineral resources is shown in Fig. 2 [9].

3.3. Establishment of priority-sequence model based on grey relational analysis

The steps of evaluating priority-sequence on the development and utilization of mineral resources based on grey relational analysis method are as follows:

(1) To establish evaluation indicator matrix

Suppose that there exists n data series, m indicators, $x_i(k)$, $k = 1, 2, \ldots, m$, define

$$(X_1, X_2, \ldots, X_n) = \begin{pmatrix} x_1(1) & & x_n(1) \\ x_1(2) & & x_n(2) \\ \vdots & \cdots & \vdots \\ x_1(m) & & x_n(m) \end{pmatrix} \quad (1)$$

where $X_i = (x_i(1), x_i(2), \ldots, x_i(m))^T$, $i = 1, 2, \ldots, n$.

(2) To determine the reference sequence

Let $x_0(k)$, $k = 1, 2, \ldots, m$ represent the reference sequence.

The reference sequence is an ideal standard of comparison. It is made up of the optimal values (or the worst values) of the evaluation indicator of priority-sequence on the development and utilization of mineral resources. We can also choose other reference standards in accordance with the evaluation objectives.