Study on the financing mode selection of overseas investment for coal mining projects

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Abstract

Outward foreign investment of coal mining project needs a large amount of money and has the characteristics of high returns and risks. The transnational financing is more difficult to manage and make decisions, under the complicated financial and legal environment. From the perspective of project sponsors, the selection of the financing model not only affects the project ownership, the cost of capital, risk sharing, etc., but also is the basis of development work of follow-up. This paper found out the influence factors of financing model selection through the ISM method, and calculated the index weight through the ANP model with unknown expert weight, based on the analysing of the existing financing modes and their respective characteristics. Then the grey target decision model was established for financing mode selection, with index weight got by the previous step.

Keywords: Overseas investment；Coal mining；Financing mode；Unknown experts' weights；ANP；Grey target decision model

1 Introduction

With the development of our country's internationalization unceasingly deepening, outward foreign investment of coal mining project has become a hot spot for investment in domestic mining enterprises and big financial group. In China, coal resources take a 2/3 share in the energy structure, which make them a absolute leading status [1]. According to statistics, the requirement of coal resources is increasing year by year. Besides, the quantity is still far away from the practical demands as imports have always outpaced exports. By the end of 2012, China's proven reserves of coal resources are 114500 million tons, accounting for 13.3% of the world with total proved reserves of 860938 million tons. However, in China, reserve-production ratio of coal is only 31, much lower than the world average level of 109. In other words, the proven coal reserves of the world are sufficient to meet the demands of global production for 109 years, while the reserves of China are only for the coming 31 years' demands [2]. Therefore, it is extremely important to obtain coal resources abroad for the present situation of our country. Since 2000, the large domestic mining enterprises have been trying to invest overseas coal project gradually, but most of them did not get the desired results. For example, the Shenhua Group invested Mongolia Tolgoi project, which made no significant progress in a few years. Lacking of preparation, the project in the Australia state of Queensland, which is invested by Wanbei Coal Group, does not enter into the implementation at present. Dialogic data [3] show that, Chinese enterprises have announced 696 million in outbound acquisitions which has reached 16 cases this year. Look from area distribution, Australia has 9 transactions with the amount of $479 million, Indonesia, Canada and Britain each has two transactions, and only one in Kyrgyzstan.

Many scholars have studied in accordance with the current situation of lacking of experience and knowledge. Such as Chengqian (2010), aiming at the problem of selecting the financing mode of coal investment projects, he analyzed the source of funds for mining financing systematically [4], explained the characteristic of 5 financing modes including "production payment", "leveraged lease", "BOT", "ABS", "PPP", and the reason that the mode of BOT project has been the most superior financing pattern in China qualitatively. Meanwhile, he put forward the collective bond financing model for the small mining enterprises creatively [5]. Chen Shikai (2007) analyzed the source of funds for different stages of international mining financing and summarized the main financing mode of each stage, on this basis, he compared the difference between domestic and foreign financing mode. Take Petro China for example [6], Dong Wei (2010) analyzed the affecting factors and design thought of overseas project financing model, and provided the suggestion on the optimization for Petro China to operate the model. Furthermore, in views of financing capability and cost [7], Xiong Qibin (2005) comparatively analyzed

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the way of overseas financing oil in Japan and USA, then provided some policy suggestion about Chinese overseas investment in oil. Yang Jie (2014) used the extension theory to choose the financing mode quantifical [8], which broke the original situation mainly conducted from qualitative analysis in the financial mode selection. However, the above four scholars all made qualitative analysis, although the last one made a quantitative analysis, the subjective index was too large and not combined the specific characteristics of the project, so it lacked the value in practical application. From this foundation, this paper creatively put forward the ANP model with unknown experts' weights and combined with the grey target decision mode, and then it would obtain a more objective result than using Analytic Hierarchy Process (AHP) and entropy weight, which provided a new method for the financial mode selection.
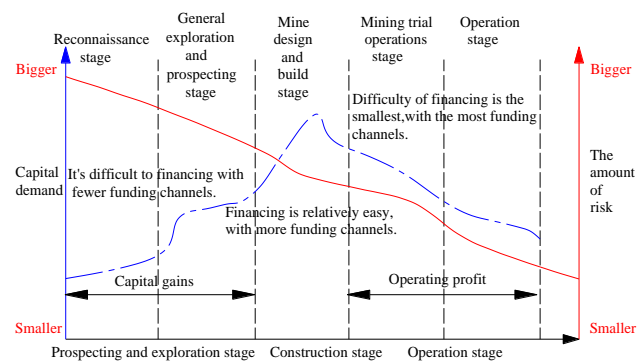

FIGURE 1 Coal resources development project phase diagram

The coal resource development projects can take different financing forms in different stages. The resource of mining project consists of venture investments, issuing bonds, syndicated loans, project financing, leasing and so

TABLE 1 The funding sources for coal development projects on different stages					
Work stage	**Proposal stage**	**Research stage**	**Design and construction stage**	**Exploitation stage**	**Operation stage**
Exploration degree	The census	Preliminary exploration	Detailed exploration	Detailed exploration	Marginal exploration
Risk level	Very high	Very high	Higher	Higher	The general
The main source of funding	Venture investment Shareholder investment	Venture investment Shareholder investment	Project financing Debt financing	Project financing Debt financing Publicly-listed	Merger and reorganization Commercial financing

2 Financing Characteristics and Sources of Colliery Project

2.1 THE CHARACTENRISTICES OF STAGE FINANCING MINING RESOURCE DEVELOPMENT PROJECT

For developing coal resources, the development process is divided into 3 stages: prospecting stage, development stage and operation stage. Each stage shows itself striking feature [9]. With the deepening of the development and the improving of resource reserves and cash flow, the needed purchase funds for investing coal enterprises will show a big leap. According to the Greenfield investment project (also known as creating investment or new investment), project financing also shows phase characteristics with the continuous development.

Since the amount of resources, quality and economic value can't be estimated, the prospecting stage has the highest lifetime risks in the project, but expenditures on it is relatively small, and the financing is the most difficult thing [10]. The development phase needs a greatest number of funds in the whole project lifecycle, the reserves and economic benefits of the future can be estimated accurately at this stage, so the risk is lower than that of prospecting stage, and it needs to work on capital raising. The operation stage offers the least risks; the demand for funds has abated gradually (FIGURE 1).

on [11]. The main funding sources for coal development projects on different stages are shown in Table 1.

2.2 THE EXISTING FINANCING MODE AND CHARACTENRISTICES

"Production payment" Ownership of products or product sales revenue as loan repayment guarantees. This model has better credit guarantee than the other models. As the creditors and debtors have high degree of independence, the ownership and control power of the project company will not be affected. This model is applicative to most resource projects, since the products are the security for loans, the resources reserves of the project required by lenders have been proven and the cash flow can precisely predict the mining project.

"Leveraged lease" The asset leasers purchase project assets and then rent to the lessees. The rental charges of the model can reduce taxation cost and not affect the ownership and control rights of the project [12]. The mode has many limited conditions. First of all, it needs a stable tax environment in the project location. Secondly, we must obtain written permission from the local tax department before the financing activities begin. Many countries have restricted this model since it has a characteristic that they should pay the rent before tax.

"BOT" (Build-Operate-Transfer) the government signs a chartered agreement on a project with private investors and empowers them to invest, finance, construct and operate within the concession period [13]. For private investors that invest overseas coal project, this mode can reduce the financial pressure of local governments and

improve the local technical level and enhance the anti-risk ability of the project. The mode will make the host government lose control of the project in the concession period, the negotiation process is so long with the local government, and the operation difficulty is great [14].

"ABS" (Asset Securitization) in this model, takes the assets as the basis and perceived benefits as the guarantee, top bond should be issued to raise funds in the capital market. Little debt on its balance sheet of original stakeholders avoids the asset quality limitations. Credit risks need the guarantee of SPV (Special Purpose Vehicle), strict conditions and to have certain assets as the basis of securitization.

"PPP" (Public-private Partnership) it is guaranteed by the assets, interests or perceived benefits to secure financing or loan which is non-recourse or limited-resource. The public sector and private investors are equal partners based on some project, they co-invest, split the risks and profits. This financing mode is applicative in more and more public infrastructure projects, as the overseas investment of coal mine project, it is very difficult to obtain the active cooperation of local government for investors and also has great difficulty in operation.

3 The Selection of Financing Mode of Outward Foreign Investment of Coal mining project

3.1 THE SELECTION OF STAGE FINANCING MODE

Combined with the difficulty of the overseas investment of coal mining project in prospecting stage and the characteristic of lower credit rating, prospecting stage generally use the internal financing mode. In stage of project construction, the financing is more complex, which should be given financing mode. The operational phase of the project is based on the operating profit. With the debt redemption and capital accumulation, project financing will be restructured or listed (FIGURE 2).
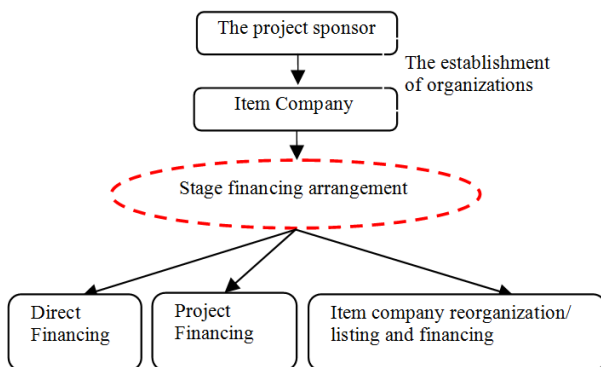

FIGURE 2 Finance modes in different stages for outward foreign investment of coal mining project

3.2 THE ANALISIS OF SELECTION FACTORS OF PROJETS FINANCING MODE IN THE CONSTRUCTION STAGE

Main factors affecting financing mode of overseas investment of coal mining project include cost of capital, capital risk, ownership of project and operation and complexity of financing mode etc. There are many differences between the above mentioned indexes has a great difference in the different investment target country. Taking "the selection of financing mode" and "influencing factors" for key words in "literature 2010-2014" years is a total of 200 articles in CNKI search. "By different scholars in two or more than two as study factors affecting [15]" as a selection criteria, they totally sort out 19 factors of the relevant financing mode selection [16]. Through the expert further investigation, they identified 14 core influence factors (such as shown in Table 2) as the focus of this paper [17].

TABLE 2. The influencing factors of financing mode selection

Sign	Index	Index explanation
S_1	The applicability	The general applicability evaluation on financing mode of target item.
S_2	Compliance of local policy law	The local policy and law on the financing mode of licensing and support.
S_3	The development degree of the capital market	Capital market acceptance of the financing mode.
S_4	Matching the applicable scope	Whether the financing mode fit for the target project.
S_5	Economy	Whether the financing mode can meet the capital demand of project.
S_6	Financing cost	The weighted cost of capital.
S_7	The preferential tax	The proportion of tax amount and the total output value.
S_8	Rationality	The rationality of the various project participants.
S_9	The rationality of risk allocation	The rationality of the sharing of risk among the various project participants.
S_{10}	The rationality of guarantee, insurance	The rationality of the guarantee of project risk.
S_{11}	Complexity	The complexity to operate the financing mode.
S_{12}	Complexity of the project financing operation	The complexity of the financing process.
S_{13}	Complexity transfer of assets and refinancing	The complexity of asset transfer and refinancing.
S_{14}	The degree of control	The project sponsor ownership of the project and the degree of control

In the above indexes, there are accurately indescribable the quantized language index, there can be a reasonable forecast of interval number index. The cost of financing, including predictable long term loan, capital financing leveraged lease cost, bond and equity capital cost, opportunity cost, can be a reasonably predicted interval number index. Due to the different financing mode, paying interest on the debt tax and rental costs are different, so the tax preferential produces different. They calculate the proportion produced by the tax amount in different financing modes and total tax calculation, and contrastively analysis, in the case of certain rights under the capital account.

4 Research on the selection model of the construction phase of the project financing mode

4.1 DETERMINING THE RELATIONSHIP BETWEEN INDEXES OF PROJECT FINANCING MODE BASED ON ISM

ISM (Interpretative Structural Modelling Method Namely: the explanation structure model) [18], was put forward by Professor America John Warfield in 1973, was a widely used modern analysis method in system engineering. The basic steps of ISM method for analysis of the relationship between the project risk:

1) According to the characteristics of the project, people should class the influence target into different category, and will denoted the first i index as $s_i(i = 1, 2, 3......)$;

2) Clearing the relationship between the indicators to build two element matrixes: determine the logical relationship between the indexes, the establishment such as two element matrixes. A shows that the column elements have influence on the row element; V indicates that the line element has the effect on the column; O said that there are no effect between the column and line elements; X said that there are effect between the column and line element.

3) The establishment of the adjacency matrix B : Establish the factors influence relationship between two-two adjacent matrix B, and b_{ij} can be converted by the two element matrix step 2. The conversion process is showed in Table 3.

TABLE 3. Corresponding element table of binary matrix converted into adjacency matrix

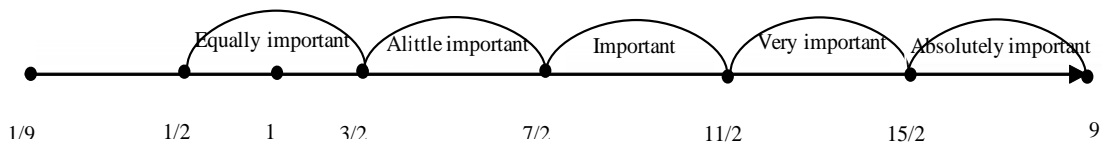| Index value	$i = j$	A	V	O	X
b_{ij}	0	0	1	0	1
b_{ji}	0	1	0	0	1

FIGURE 3 Corresponding language meaning of triangular fuzzy number

4) Computing reachable matrix：The adjacency matrix of B, by using of Boolean algebra rule of operation and on the law, can get the reachable matrix R. The reachable matrix B, with the number of elements [19] in each row of the number 1, according to the order from less to more, it is rearranged from the top down .according to the order of the new row element, it adjusts the column elements with the same order, forms matrix reordering reachable matrix, removes the reordering of

indirect relationship matrix and reflexive matrix, and gets the reordering reachable matrix [20].

4.2 THE UNKONWN INDEX WEIGHE OF FUZZY NETWORK MODEL BASED ON THE EXPERT WEIGHT

ANP (Analytic Network Process Namely: network analysis) ANP solves the strategy problems that are complex and not quantized by the establishment of the network structure model [21]. ANP is consisting of a control layer P and network layer C, and C_i contains elements as $e_{i1}, e_{i2}, \cdots, e_{in}$. Previous ANP models were evaluated by single expert, which was comprehensive and lacks confidence, this paper on the basis of the original model established the unknown group decision model of expert weight .The improved ANP model has the following 3 main steps:

1) Establishment of fuzzy judgment matrix

Judge matrix qualitative description under the form of triangular fuzzy numbers. The different relationships in indexes divided matrix structure into two cases. When the index are independent from each other, it can accord to AHP method that the two- two comparison are required in the same standards; When the indexes has Mutual relationship, it needs to set the main criteria and sub criteria.

Triangular fuzzy number is expressed in the form of $M = (l, m, u)$, $l, m, u \in R(Real \ \ number)$ $l \leq m \leq u$ and they respectively represent the minimum value index value, most probable value and maximum value. When they are equal, Triangular fuzzy number reduced to real number. Setting up $\mu_{ij} \in [\frac{1}{9}, 9]$, a based on some criteria of an expert, is a degree that B index is more important than C index .The μ_{ij} of the corresponding language meaning is showed in figure 3. When the reciprocal of $\mu_{ij} \in [\frac{1}{9}, 1)$ and $\mu_{ij} \in (1, 9]$ is corresponding, the language meaning changes into antisense. Different experts` description on the same set of fuzzy judgment matrix is showed as formula (1):

$$A^k = \begin{bmatrix} 1 & (l_{12}^k, m_{12}^k, u_{12}^k) & ... & (l_{1n}^k, m_{1n}^k, u_{1n}^k) \\ (l_{21}^k, m_{21}^k, u_{21}^k) & 1 & ... & (l_{2n}^k, m_{2n}^k, u_{2n}^k) \\ ... & ... & ... & ... \\ (l_{n1}^k, m_{n1}^k, u_{n1}^k) & (l_{n2}^k, m_{n2}^k, u_{n2}^k) & ... & 1 \end{bmatrix} (1)$$

2) Steps to determine the weight of expert based on minimal total deviation:

①Calculation with the same group data of different experts scoring average, The expression as：

$$\sum_{k=1}^{T}\frac{M_{ij}}{T}=(l_{ij}^{0},m_{ij}^{0},u_{ij}^{0})$$, Where T is the total number of experts.

② The same set of data, expert score to the mean Euclidean distance as:

$$d_{ij}^k=\frac{\sqrt{3}}{3}\sqrt{(\omega_k l_{ij}^k-l_{ij}^{0})^2+(\omega_k m_{ij}^k-m_{ij}^{0})^2+(\omega_k u_{ij}^k-u_{ij}^{0})^2}$$
(2)

③ Expert weights are determined based on the minimum total deviation:

$$\begin{cases}\sum_{k=1}^{T}\omega_k=1,\omega_k\in(0,1)\\ \min\sum_{k=1}^{T}\sum_{i=1}^{n}\sum_{j=1}^{n}d_{ij}^k\end{cases}$$
(3)

④ Weighted aggregation matrix judgment:

$$\tilde{A}=\left[\sum_{k=1}^{T}\omega_k A^k\right]$$
(4)

3) Index weight calculation based on the fuzzy network model

As a criterion to the e_{j1} elements in C_j , other elements in the group of C_i , e_{in_i} has an important degree of comparative analysis with e_{j1} .which Constructively judges matrix and calculates the weights of experts,

$\tilde{A}^{(l)}=(\tilde{l}_{ij})_{n\times n}$, $\tilde{A}^{(m)}=(\tilde{m}_{ij})_{n\times n}$, $\tilde{A}^{(u)}=(\tilde{u}_{ij})_{n\times n}$ respectively indicates the weighted fuzzy judgment matrix, the lower limit of the most likely value and fuzzy limit matrix respectively. which Were normalized feature vectors of the solution.

$$\begin{cases}x^{(l)}=(x_1^{(l)},x_2^{(l)},...,x_n^{(l)})^T\\ x^{(m)}=(x_1^{(m)},x_2^{(m)},...,x_n^{(m)})^T\\ x^{(u)}=(x_1^{(u)},x_2^{(u)},...,x_n^{(u)})^T\end{cases}$$
(5)

Using the fuzzy cut set analysis in analyzing the conception of fuzzy weights of defuzzification, which switch fuzzy weight into non fuzzy results. According to the definition of the coefficient of risk acceptance decision makers $s\in(0,1)$, $t\in(0,1)$. The weight can be no defuzzified [23].

$$v=(t+1)\times[v_i^u-s\times(v_i^u-v_i^m)]-t\times[s\times(v_i^m-v_i^l)+v_i^l]\quad(6)$$

It can calculate the ranking vector network elements (weight) by the formula (6), and empathy can be obtained with respect to the other elements of the ranking vector. If the C_j element is not affected by the elements in the C_i , obtaining $v_{ij}=0$. Priority vector, which influence each other in all the network layer elements, is combined to get a control element in the p_s under the super matrix V .Also can get other control elements of the super matrix.

$$v_{ij}=\begin{bmatrix}v_{11}&v_{12}&\cdots&v_{1N}\\ v_{21}&v_{22}&\cdots&v_{2N}\\ \vdots&\vdots&\vdots&\vdots\\ v_{N1}&v_{N2}&\cdots&v_{NN}\end{bmatrix}$$
(7)

Weighted super matrix in the structure system [24]. First of all, to control the elements of the P as the criterion, all the kinds of elements under the P are importantly compared with the C criteria. Getting a normalized vector row sequence $(a_{1j},a_{2j},\cdots,a_{Nj})^T$. In order to obtain a weighted matrix (equation (8) expresses), a_{ij} elements in the matrix is indicates that the influence of weight of i elements is on o the j elements in the control elements of the p_s criterion. If two elements group had no effect, they are expressed by $a_{ij}=0$ .so V weighted super matrix is $\overline{V}=A\times V=(a_{ij}\times v_{ij})(i=1,2,\cdots,N;j=1,2,\cdots,N)$. The normalized limit vector for weighted super matrix $\overline{V}^\infty=\lim_{n\to\infty}\overline{V}^n$, getting the value of the weight of each index.

$$A=\begin{bmatrix}a_{11}&\cdots&a_{1N}\\ \vdots&\vdots&\vdots\\ a_{N1}&a_{N2}&a_{NN}\end{bmatrix}$$
(8)

4.3 THE CONSTRUCTION STAGE FINANCING MODE AND MULTI GREY TARGET DECISION

It establishes the Mixed Multi grey target model [25]-[27], in the index weight of the known cases, according to the traditional TOPSIS theory. According to the different nature of the indicators, indicators are divided into interval of real numbers, direct measurement of computation can be predicted and the triangular fuzzy numbers based on expert cognition.

In a decision problem, there are n plan, m evaluation index, remarking $i=\{1,2,...,n\}$, $j=\{1,2,...,m\}$ .The quantized data of the first n scheme and data first m is noted as A. According to the types of the index data, it can be divided into the real number, interval number, and triangular fuzzy numbers. Subscript three index set respectively M_1 , M_2 , M_3 , the matrix form of $X=(X_{ij})_{n\times m}$ as follows：

$$X_{ij}=\begin{cases}X_{ij}&j\in M_1,\ i\in N\\ \left[X_{ij}^L,X_{ij}^U\right]&j\in M_2,\ i\in N\\ \left[X_{ij}^L,X_{ij}^M,X_{ij}^U\right]&j\in M_3,\ i\in N\end{cases}$$
(9)

In order to the unified indicators of investment decision-making role, the index presented above is divided into benefit and cost type, and is respectively normalized [28].

$$\text{Real number} \begin{cases} \text{Benefit type:} \ r_{ij} = X_{ij} / \sqrt{\sum_{i=1}^{n} X_{ij}^2} \\ \\ \text{Cost type:} \ r_{ij} = (1/X_{ij}) / \sqrt{\sum_{i=1}^{n} (1/X_{ij})^2} \end{cases} \quad (10)$$

$$(i \in N, \ j \in M)$$

$$\text{Interval number} \begin{cases} \text{Benefit type:} \begin{cases} r_{ij}^L = X_{ij}^L / \sqrt{\sum_{i=1}^{n} (X_{ij}^U)^2} \\ r_{ij}^U = X_{ij}^U / \sqrt{\sum_{i=1}^{n} (X_{ij}^L)^2} \end{cases} \\ \text{Cost type:} \begin{cases} r_{ij}^L = (1/X_{ij}^U) / \sqrt{\sum_{i=1}^{n} (1/X_{ij}^L)^2} \\ r_{ij}^U = (1/X_{ij}^L) / \sqrt{\sum_{i=1}^{n} (1/X_{ij}^U)^2} \end{cases} \end{cases}$$

$$(i \in N, \ j \in M)$$

(11)

$$\text{Triangular fuzzy numbers} \begin{cases} \text{Benefit type:} \begin{cases} r_{ij}^l = X_{ij}^l / \sqrt{\sum_{i=1}^{n} (X_{ij}^u)^2} \\ r_{ij}^m = X_{ij}^m / \sqrt{\sum_{i=1}^{n} (X_{ij}^m)^2} \\ r_{ij}^u = X_{ij}^u / \sqrt{\sum_{i=1}^{n} (X_{ij}^l)^2} \end{cases} \\ \text{Cost type:} \begin{cases} r_{ij}^l = (1/X_{ij}^u) / \sqrt{\sum_{i=1}^{n} (1/X_{ij}^l)^2} \\ r_{ij}^m = (1/X_{ij}^m) / \sqrt{\sum_{i=1}^{n} (1/X_{ij}^m)^2} \\ r_{ij}^u = (1/X_{ij}^l) / \sqrt{\sum_{i=1}^{n} (1/X_{ij}^u)^2} \end{cases} \end{cases}$$

$$(i \in N, \ j \in M)$$

(12)

Because of the complexity and uncertainty of the influence index, grey target decision model does not necessarily have the absolute optimal solution, but as far as possible to get a satisfactory solution. Decision thinking is a standardized unified dimensional Euclidean space for all of the index set, the index distribution in the same on the grey target [29]. To find the target position, calculate the distance to target centre of each scheme, and comparison sorting. Because of different data types, target position according to the formula (13) determination [30].

$$r_j^0 = \begin{cases} \max \left\{ r_{ij} \mid j \in M_1, \ i \in N \right\} \\ \max \left\{ \dfrac{r_{ij}^L + r_{ij}^U}{2} \mid j \in M_2, \ i \in N \right\} \\ \max \left\{ r_{ij}^m \mid j \in M_3, \ i \in N \right\} \end{cases} \quad (13)$$

A bull's eye for matrix $r_0 = (r_1^0, r_2^0, \dots r_m^0)$. The r_{ij} and the r_0 `distance is:

$$d_{ij} = \begin{cases} d_{ij}^{M_1} = |r_{ij} - r_{i_0 j}| & (j \in M_1, \ i \in N) \\ d_{ij}^{M_2} = \dfrac{\sqrt{2}}{2} \sqrt{(r_{ij}^L - r_{i_0 j}^L)^2 + (r_{ij}^U - r_{i_0 j}^U)^2} & (j \in M_2, \ i \in N) \\ d_{ij}^{M_3} = \dfrac{\sqrt{3}}{3} \sqrt{(r_{ij}^L - r_{i_0 j}^L)^2 + (r_{ij}^M - r_{i_0 j}^M)^2 + (r_{ij}^U - r_{i_0 j}^U)^2} & (j \in M_3, \ i \in N) \end{cases} \quad (14)$$

d_{ij} is the distance of the first j index in the i scheme and bull's eye, so The overall target of i scheme from the formula (15) are shown, Where v_j is the weight of each index.

$$d_i^2 = \sum_{i=1}^{n} \sum_{j=1}^{m} v_j (d_{ij})^2 \quad (15)$$

4.4 CASE ANALYSIS

Some overseas coal resources development project, located in country A, project reconnaissance stage has been completed. Researching on two countries` political ,economic and other relations ,it can calculate loan interest rate, leveraged lease financing costs, interest rate bonds index interval by experience, then expert group carries on the appraisal to the project.

1) According to ISM basic steps, it sets up a two financing mode selection matrix, as shown in Table 4. To convert the adjacency matrix and reachable matrix is calculated as shown in table 5, ISM level hierarchical structure is shown in Fig4. Knowing by reordering the reachable matrix, the system is divided into two layers, the first layer includes: and S2、S3、S4 are respectively showed in a reflexive matrix. It can show hierarchical structure level in Figure 4.

TABLE 4 The adjacency matrix of the influencing factors of financing mode

Factors	S₂	S₃	S₄	S₅	S₆	S₇	S₈	S₉	S₁₀	S₁₂	S₁₂	S₁₃	S₁₄
S₁	A	A	A	0	0	0	0	0	0	0	0	0	0
S₂		X	X	0	0	0	0	0	0	0	0	0	0
S₃			X	0	0	0	0	0	0	0	0	0	0
S₄				0	0	0	0	0	0	0	0	0	0
S₅					A	A	0	0	0	0	0	0	0
S₆						O	0	0	0	0	0	0	0
S₇							0	0	0	0	0	0	0
S₈								A	A	0	0	0	0
S₉									X	0	0	0	0
S₁₀										0	0	0	0
S₁₁											A	A	0
S₁₂												0	0
S₁₃													0

TABLE5 Reordering accessible matrix

Factors	S₁	S₁₄	S₈	S₁₁	S₅	S₆	S₇	S₁₂	S₁₃	S₉	S₁₀	S₂	S₃	S₄
S₁	1	0	0	0	0	0	0	0	0	0	0	0	0	0
S₁₄	0	1	0	0	0	0	0	0	0	0	0	0	0	0
S₈	0	0	1	0	0	0	0	0	0	0	0	0	0	0
S₁₁	0	0	0	1	0	0	0	0	0	0	0	0	0	0
S₅	0	0	0	0	1	0	0	0	0	0	0	0	0	0
S₆	0	0	0	0	0	1	1	0	0	0	0	0	0	0
S₇	0	0	0	0	1	0	1	0	0	0	0	0	0	0
S₁₂	0	0	0	1	0	0	0	1	0	0	0	0	0	0
S₁₃	0	0	0	1	0	0	0	0	1	0	0	0	0	0
S₉	0	0	1	0	0	0	0	0	0	1	1	0	0	0
S₁₀	0	0	1	0	0	0	0	0	0	1	1	0	0	0
S₂	1	0	0	0	0	0	0	0	0	0	0	1	1	1
S₃	1	0	0	0	0	0	0	0	0	0	0	1	1	1
S₄	1	0	0	0	0	0	0	0	0	0	0	1	1	1

2) The construction of fuzzy network model to calculate the index weight

Constructing judgment matrix based on triangular fuzzy number [31].

① Calculating One class index weight(One class index are independent from each other, and it can be calculated directly by AHP method). The type (16) level
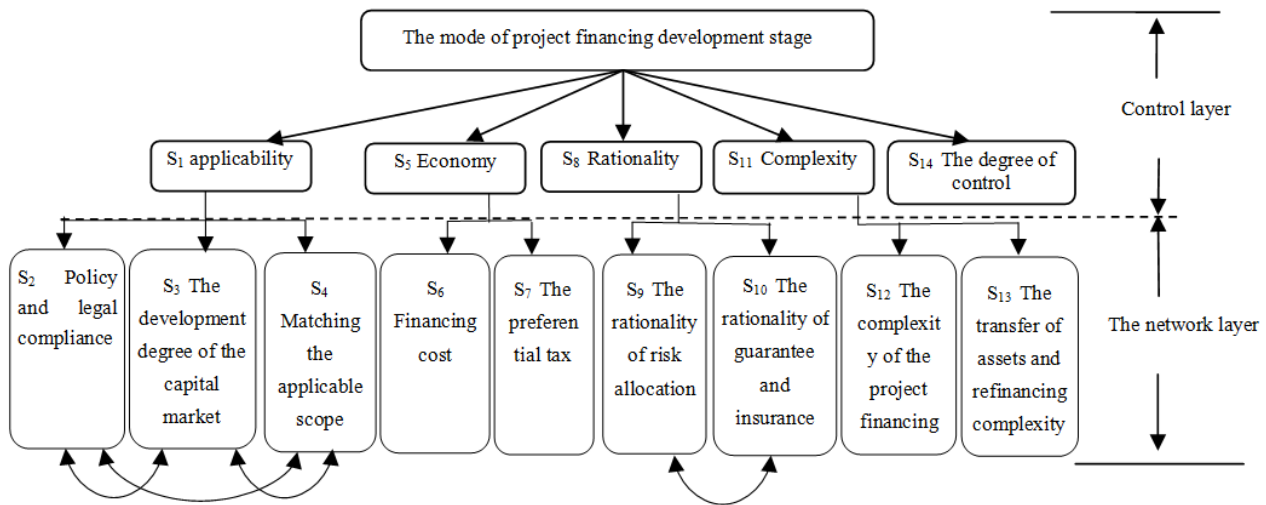

FIGURE 4 The hierarchical chart of the influencing factors got by ISM

indicators, given by 4 experts, shows that the judgment matrix respectively present as A^1、A^2、A^3、A^4.

$$A^1 = \begin{array}{c} \\ S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \end{array} \begin{bmatrix} (1,1,1) & (1,\frac{3}{2},\frac{7}{2}) & (\frac{7}{2},\frac{10}{2},\frac{13}{2}) & (\frac{13}{2},\frac{15}{2},\frac{17}{2}) & (\frac{5}{2},\frac{7}{2},\frac{11}{2}) \\ & (1,1,1) & (\frac{5}{2},\frac{7}{2},\frac{9}{2}) & (\frac{9}{2},\frac{11}{2},\frac{14}{2}) & (1,\frac{3}{2},\frac{5}{2}) \\ & & (1,1,1) & (1,\frac{3}{2},\frac{6}{2}) & (\frac{2}{5},\frac{2}{3},1) \\ & & & (1,1,1) & (\frac{2}{10},\frac{2}{9},\frac{2}{7}) \\ & & & & (1,1,1) \end{bmatrix}$$

$$A^2 = \begin{array}{c} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \end{array} \begin{bmatrix} (1,1,1) & (\frac{3}{4},1,\frac{5}{4}) & (\frac{8}{2},\frac{11}{2},\frac{12}{2}) & (\frac{15}{2},\frac{16}{2},\frac{17}{2}) & (\frac{7}{2},\frac{9}{2},\frac{11}{2}) \\ & (1,1,1) & (\frac{5}{2},\frac{7}{2},\frac{9}{2}) & (\frac{9}{2},\frac{11}{2},\frac{13}{2}) & (\frac{3}{2},\frac{5}{2},\frac{7}{2}) \\ & & (1,1,1) & (\frac{3}{2},\frac{4}{2},\frac{5}{2}) & (\frac{2}{5},\frac{1}{2},\frac{2}{3}) \\ & & & (1,1,1) & (\frac{1}{4},\frac{1}{3},\frac{1}{2}) \\ & & & & (1,1,1) \end{bmatrix}$$

$$A^3 = \begin{array}{c} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \end{array} \begin{bmatrix} (1,1,1) & (\frac{5}{2},\frac{7}{2},\frac{9}{2}) & (\frac{11}{2},\frac{12}{2},\frac{13}{2}) & (\frac{15}{2},\frac{16}{2},\frac{19}{2}) & (\frac{3}{2},2,\frac{5}{2}) \\ & (1,1,1) & (2,3,4) & (\frac{8}{2},\frac{10}{2},\frac{13}{2}) & (\frac{2}{9},\frac{4}{9},\frac{3}{2}) \\ & & (1,1,1) & (\frac{5}{4},\frac{4}{2},\frac{6}{2}) & (\frac{2}{10},\frac{4}{17},\frac{2}{7}) \\ & & & (1,1,1) & (\frac{2}{15},\frac{2}{13},\frac{2}{10}) \\ & & & & (1,1,1) \end{bmatrix}$$

$$A^4 = \begin{array}{c} \\ S_1 \\ \\ S_2 \\ \\ S_3 \\ \\ S_4 \\ S_5 \end{array} \begin{bmatrix} (1,1,1) & (1,\frac{3}{2},\frac{7}{2}) & (\frac{13}{2},\frac{15}{2},\frac{17}{2}) & (\frac{7}{2},\frac{10}{2},\frac{13}{2}) & (\frac{5}{2},\frac{7}{2},\frac{11}{2}) \\ & (1,1,1) & (\frac{11}{2},\frac{13}{2},\frac{15}{2}) & (\frac{9}{4},\frac{8}{2},\frac{9}{2}) & (1,\frac{5}{4},\frac{3}{2}) \\ & & (1,1,1) & (\frac{4}{7},1,\frac{4}{3}) & (\frac{2}{7},\frac{2}{6},\frac{2}{5}) \\ & & & (1,1,1) & (\frac{2}{5},\frac{2}{3},1) \\ & & & & (1,1,1) \end{bmatrix} \quad (16)$$

Through the weight of Mat lab genetic algorithm toolbox after 100 times of iterative computation, 4 experts' weight was as: (0.872, 0.0442, 0.043, and 0.041). Figure 5 is the genetic algorithm convergence process of calculating the weight of experts. Figure 6 (a), (b), (c) respectively denote the distribution map data thresholds, intermediate values, limit after expert grading and weighting information aggregation. Weighted judgment matrix calculation of 4 experts. The case used in the calculation of risk acceptance $s = t = 0.5$. Computing with S_1 as a layer of index weight criterion for

$$A = (0.4432,0.2618,0.0831,0.0494,0.1625)^T \quad (17)$$

②Calculation of two level index weight according to the ANP monolayer steps, the establishment of weighted super matrix and obtaining the limit matrix $\lim_{n\to\infty}(A\times V)^n$, which obtains the weight index of Financing mode selection influence and it's showed in Table 6.

TABLE 6 Effects of selection index weight value and financing mode

Factors	Weight	Secondary indexes	Weight	Synthetic weight	Comprehensive ordering
S_1	0.4432	S_2	0.8031	0.355934	1
		S_3	0.0631	0.027966	8
		S_4	0.1338	0.059300	5
S_5	0.2618	S_6	0.8360	0.218865	2
		S_7	0.1640	0.042935	6

S_8	0.0831	S_9	0.7420	0.061660	4
		S_{10}	0.2580	0.021440	9
S_{11}	0.0494	S_{12}	0.8130	0.040162	7
		S_{13}	0.1870	0.009238	10
S_{14}	0.1625		1.0000	0.162500	3

$$r_0 = \{(0.45, 0.517, 0.582), (0.404, 0.512, 0.651),$$
$$(0.601, 0.795, 1.06), [0.384, 0.596],$$
$$[0.452, 0.458], (0.404, 0.512, 0.651), \qquad (18)$$
$$(0.472, 0.575, 0.655), (0.404, 0.584, 0.855)$$
$$(0.31, 0.84, 0.23), (0.454, 0.573, 0.72)\}$$

Thus to determine the scheme of the distance to target center matrix:

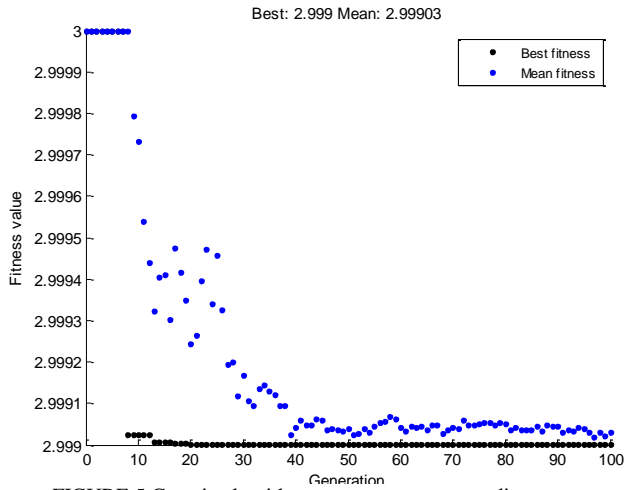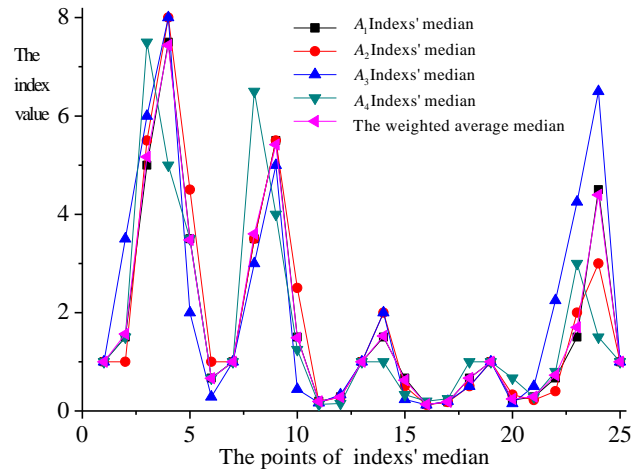FIGURE 5 Genetic algorithm convergence process diagram

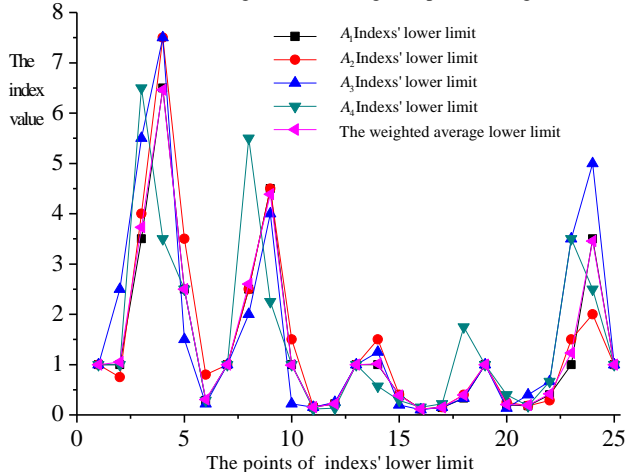FIGURE 6 The weighted data distribution (b)

FIGURE 6 The weighted data distribution (a)

TABLE7 Qualitative indicators quantified in triangular fuzzy numbers

Qualitative description	Extra low	Very low	Low	The general	High	Very high	Extra high
Triangular fuzzy numbers	(0,0,0.1)	(0.1,0.2,0.3)	(0.2,0.3,0.4)	(0.4,0.5,0.6)	(0.6,0.7,0.8)	(0.8,0.9,1)	(0.9,1.0,1.0)

3) The establishment of grey target decision model of financing mode selection

To quantify the qualitative index by 7 scale linguistic variables, Table 7 is qualitative indexes of triangular fuzzy number of quantization table.

According to the project characteristics of collection Figure 4 index data and linguistic evaluation set as shown in Table 8.

The use of mixed type data standardization method (formula (10) to (15)), changes the sample matrix into standardization decision matrix:

According to the R to the bull's eye for: expert weights reduces the original ANP model single characteristics of the evaluation results are caused by
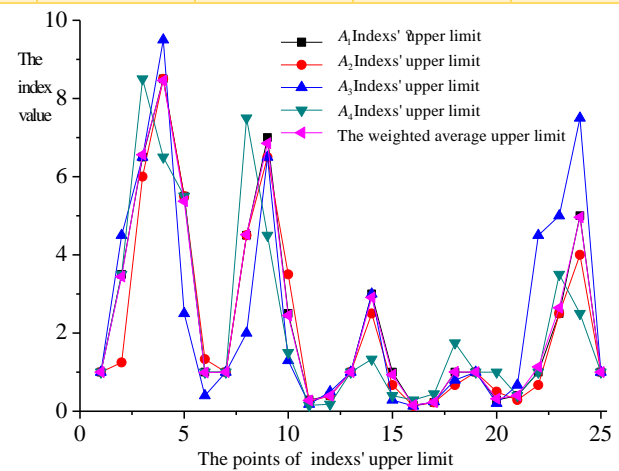

FIGURE 6 The weighted data distribution (c)

Factors / Financing mode	Payment for products	Leveraged lease	BOT	ABS	PPP
TABLE 8 Qualitative indicators quantified in triangular fuzzy numbers expert decision.					
S₂ Compliance of local policy law	Extra high	The general	Extra high	Extra high	high
S₃ The development degree of the capital market	high	high	Very high	high	Very high
S₄ Matching the applicable scope	The general	Very low	Low	Very high	Low
S₆ Financing cost (%)	[10.3,13.1]	[11.4,12.7]	[9.2,11.7]	[9.8,12.6]	[9.2,11.5]
S₇ The preferential tax (%)	[14.8,14.9]	[14.5,14.6]	[14.9,15]	[14.7,14.8]	[14.9,15.1]
S₉ The rationality of risk allocation	high	high	Very high	high	Very high
S₁₀ The rationality of risk allocation	high	The general	Very high	high	Extra high
S₁₂ The complexity of the project financing operation	The general	The general	Very high	Very high	Very high
S₁₃ he complexity of the transfer of assets and refinancing the complexity	The general	The general	Very high	Extra low	Very high
S₁₄ The degree of control	Very high	Very high	Extra low	Very high	Extra low

$$D = \begin{bmatrix} 0 & 0.116 & 0.363 & 0.056 & 0.009 & 0.116 & 0.154 & 0 & 1.07 & 0 \\ 0.247 & 0.116 & 0.635 & 0.085 & 0 & 0.116 & 0.271 & 0 & 1.07 & 0 \\ 0 & 0 & 0.544 & 0.004 & 0.012 & 0 & 0.045 & 0.303 & 1.235 & 0.451 \\ 0 & 0.116 & 0 & 0.035 & 0.006 & 0.116 & 0.154 & 0.303 & 0 & 0 \\ 0.142 & 0 & 0.544 & 0 & 0.014 & 0 & 0 & 0.303 & 1.235 & 0.564 \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_{10} \end{bmatrix} \quad (19)$$

The weight showed in the table 7 is solved into the evaluation results for each scheme, as follows: $D = [0.058, 0.17, 0.131, 0.034, 0.198]$. So ABS project financing mode is optimal in the case.

5 Conclusions

1) Find out the main factors that affect the overseas coal mine project financing mode selection, and analyzed the relationship between the indexes by ISM model.
2) By improving ANP model, the importance degree of choice impact indicators in financing model can be calculated. Unknown group decision ANP model of strong subjectivity, which avoids the possibility of the evaluation results from the actual bias caused by a single expert.

3) In the index weight of the known cases, establish the decision model of grey target. By investigating the background information of Investigation of the investment subject, the indexes are given descriptive language or quantitative value. Though the grey target decision model, different nature index information will be concentrated. Based on the theory of TOPSIS, select the target distance minimum financing model as the optimal financing mode of the project.

4) The model and method In this paper is used in coal mine, overseas financing mode selection of this complex decision-making problem, which has the very strong guiding role and has strong operability in view of the different project.

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