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Research on assessing eco-cycle industry chain of mineral resources from the perspective of innovation-driven

China has strongly advocated the green development concept for cycle economy and ecological economy, which completely brings the new opportunity and challenges for the mineral industry. Therefore, to transform and update the mineral resources industry chain into an eco-cycle industry chain is the development directions for the mining companies. This article proposes the four aspects of economic operation, R&D, industry chain environmental impact and eco-cycle innovation to establish the green evaluation index system via AHP and expert scoring method, and combine with Entropy-TOPSIS model, and we make a case study for listed mining companies in China's autonomous region. The findings of result analysis are that the construction of eco-cycle industry chain of china autonomous region listed mineral resources companies lies in primary stage, to achieve the transformation of the industry chain is essential, and to establish the concept of green development and increase investment in green technology contributes to the transformation and upgrading of the industry chain.

Keywords: *Eco-cycle industry chain, index system, entropy-TOPSIS, mineral resources.*

1. Introduction

Production activities are important prerequisites for communication and development between human and material systems. Industry chains are economic activities among various departments. In the circular economy system, if production activities and industry chains reach mutually beneficial and cooperative status, it means they complete the ecological cycle of economic activities in a certain sense [1]. As the basic veins of China's production activities, listed companies are the core of national industry chain, therefore, the exploitation and production of mineral resources is as one of the main production activities in China, and the operation of listed mining companies' industry chain affects the national economy directly. However, the use of mineral resources with the traditional development mode has brought the phenomena of ecological environment destruction in the mining area [2], and also some of the mineral enterprises are in trouble, the traditional extensive growth path at the cost of environment is no longer suitable for the development of cycle economy and the strategic requirement of sustainable development. In the first year of the 13th Five-Year Plan, the State Council has made a series of overall planning on China's current environmental situation and future major environmental protection issues, and offered basic strategic suggestions from seven aspects, including greenization of national economy, functionalization of national land space, legalization of environmental protection, marketization of environmental supply, scientization of decision regulation, diversification of governing subject, and publicity of environmental information [3], which has led the companies to give up the GDP oriented doctrine, and apply the green development concept into practice of production plans [4] and also pointed out a development path for listed mining companies.

Currently, the system of ecological industry chain also keeps developing and improving, and the mining companies start to construct ecological industry chain. Therefore, it is especially important to build a green evaluation index system for eco-cycle industry chain for assessing its implementation effect. There already exists many literatures on evaluation index system. For instance, some pointed out that the combinations of quality and quantity, practicability and scientificity, locality and instructiveness, systematicness, integrality and hierarchy, main component and independence were the basic principles of establishing cycle economic evaluation index system [5-6]. On this basis, researchers elaborated the following construction method of evaluation index system. For instance, based on RMMER model, combined with application of ecology in mining ecological environment evaluation system, Feng et al. (2008) adopted quantitative method of factor value assignment to put forward the 3D quantitative evaluation model system for

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ecological environment of metal mines [7]. From the perspective of green value chain, fuzzy analytic hierarchy process (AHP) was used to measure and evaluate the green degree of green value chain [8]. Based upon "expense-benefit" economic analysis, Liu (2012) established the green and economic evaluation index system for mining companies from four aspects – production economy, environmental protection, rational utilization of resources, energy saving and consumption reduction [9]. On the basis of balance scored card, Xun (2016) constructed the performance index evaluation system of green supply chain from four dimensions of finance, customer service, internal operation, and study and development [10]. Liu and Liang (2014) built the evaluation index system of ecological industry chain from external influential index, ecological industry chain company index, and overall index of ecological industry chain system [11]. Zhou et al. (2016) combined quantitative index selection method with R cluster and factor analysis to build the green industry evaluation system including three criterion layers of green production, green consumption, and green environment [12]. Tang et al. (2016) used fuzzy analytic hierarchy process to build the energy saving evaluation system of green coal mountain while taking energy conservation, pollutant emission reduction, comprehensive support, technology research and comprehensive energy consumption per unit output value, solid waste discharge standard rate, energy saving laws and regulations as evaluation indicators [13]. Wu (2016) measured the green efficiency of industries in Qinghai, Henan and Fujian province by ultra-efficient DEA window model, and analyzed the driving factors of regional industrial green efficiency evolution [14]. Du et al. (2016) adopted BBC model and MPI index to evaluate the operation efficiency of cycle economy of Baotou Steel Group statically and dynamically [15].

Researches on green index system abroad were relatively earlier than the domestic. In the 1990s, it has put forward the idea to set up the index system including economy, society, ecology. In recent years, the foreign researches mainly focused on the aspects of introduction to sustainability indicators, definitions and selections. Such as showing the selection of environmental performance indicators for sustainable port development and presenting that the environmental performance indicators are divided into management performance indicators (MPIS), operational performance indicators (OPIS) and environmental condition indicators (ECIS) [16]. Tarantini et al. (2011) used Delphi, LCA technique to select indicators to evaluate the green public procurement [17]. Mata et al. (2013) selected the sustainable indicator including LCEE, FER, GW, LUI and CSCE to evaluate the biofuels [18], and Verger et al. (2014) defined the integrating ecological, carbon and water footprint indicators [19]. Then Mascarenhas et al. (2015) combined stakeholders' participation and data reduction techniques to select the sustainability indicators to monitor spatial plans [20], and Bluszcz (2016) set a comparative analysis of selected synthetic indicators including sustainable society index (SSI), environmental performance index (EPI) and ecological footprint to measure the sustainable development on the regional, national and international level [21]. Besides, fuzzy-DEMATEL and analytical network process (ANP) were taken advantage of to evaluate the successful GSCM implementation in the mining industry [22] and so on.

Through the above literatures, the domestic researches tend to take advantage of various methods to have an evaluation with examples, and the foreign researches tend to explore the specific kind of indicators and the method of indicator selections. In addition, in terms of the autonomous regions in China, the mineral resources are abundant, but the ecological environment is fragile and the economy is relatively backward. And the mining industry as their main way of economic development, has caused enormous damage to the environment, so to form the ecological industry chain is the inevitable choice for the autonomous regional listed mining companies to develop themselves, and the application effect of the ecological industry chain not only contributes to the improving of local economy environment, also, plays a positive role in promoting national unity and stabilization.

Therefore, this paper uses Entropy-TOPSIS to construct green evaluation index system of eco-cycle industry chain for mineral resources, and applies the system to mining companies located in China's autonomous region for empirical analysis, so as to understand the situation of the ecological industry chain of them and promote the further development of the eco-cycle chain.

2. Eco-cycle industry chain

2.1 Definition of eco-cycle industry chain

2.1.1 Definition of eco-cycle industry chain

Eco-cycle industry chain refers to the union of companies bonded by resources (raw materials, by-products, information, fund, talents) in cohesive industrial relations, which imitates the producer, consumer and decomposer in the natural ecosystem and guarantees the circular flow of resources in regional scale.

2.1.2 Mineral resources regional eco-cycle industry chain

The mineral resources regional eco-cycle industry chain imitates the principle of food chain in natural ecosystem and uses products, byproducts and wastes of mineral resources regional industry to link different production processes (links) into a chain-like resource utilization relation, and thus realizing the regional circular flow of resources in mineral resources area.

2.2 Integration mechanism of mineral resources regional eco-cycle industry chain

2.2.1 Vertical extension of mineral resources regional eco-cycle industry chain

The vertical extension of mineral resources regional eco-cycle industry chain is based on the theory of "key species". The essence of the "key species" theory lies in the decisive role of "key species" in maintaining the composition and diversity of ecosystem community. The "key species" industry of mineral resources should be the one which consumes and transmits the maximum substance, reaches the largest scale in mine industry and trade, leads and restrains the development of other industries and trades. It should also take up the regional central position, be the "core of the chain" of mineral resources regional eco-cycle industry chain, and plays an essential role in structure maintenance and development of ecological mine industry.

Take the coal resource region as an example. The coal resource region is coal resource exploitation based. It can be told that coal industry is the "key species" of mineral resources region. Therefore, the vertical integration of coal resource regional eco-cycle industry chain should follow the principle of economies of scale, and regard the coal industry as the "core of the chain" and coal resource as the material basis to form an industry chain of clean energy, secondary energy and chemical conversion and to make the fullest use of coal resources. The vertical industry chains of mineral resources are: coal mining - power generation – electricity for industrial and agricultural production and household; coal mining-washing processing-coal chemical industry-market, etc.

2.2.2 Transverse coupling of mineral resources regional eco-cycle industry chain

It can be told from the characteristics of the ecosystem that the food chain in the ecological system has to adapt to the nature, so it should go through complicated evolution, and eventually form a stable food network for survival and development. The mineral resources regional ecosystem also keeps changing. It will interact with other eco-cycle industry chains and be coupled into a complex ecological cycle industry chain structure according to causality relationship in the process of its formation and development. Therefore, the transverse coupling what is based on the vertical coupling of eco-cycle industry chain is essential.

The transverse coupling of mineral resources regional eco-cycle industry chain is built on the design principle of "adding link", "unlink" and "processing link" and the material basis including byproduct, waste and associated resources from mineral resources exploitation in accordance with economies of scale. It will eventually form diversified industries, maximise the comprehensive usage and recycling of resources, and reduce waste discharge. For instance, coal mineral resources region can extend several transversely coupled eco-cycle industry chains based on vertical industry chain structure such as coal mining - coal gangue - power generation; coal mining - gangue - land reclamation - farmland; kaolin - chemical engineering– market, etc.

2.2.3 Mixed integration of mineral resources eco-cycle industry chain

The mineral resources industry has a strong industrial radiation capacity and will derive non-mineral industry related to mineral resources production and exploitation in the development and evolution process, such as logistics, machinery, construction, environmental protection, chemical industry, etc. In addition, the mineral resources ecological industry has brought damage to the environment and waste resources. Thus it is crucial to transit and upgrade the structure of mineral resources industry. The mixed integration of mineral resources follows the principle of economic growth and takes the non-mining industry and mining subsidence area as the material basis. By this means, it integrates the eco-cycle industry chain by category, constructs the eco-cycle industry chain, and forms multi-dimensional industrial pattern.

In the meanwhile, the mixed integration of mineral resources eco-cycle industry chain will help to integrate the eco-cycle industry chain of non-mining industry from linear development to circular economy thinking and from extensive to intensive growth [23].

Through vertical extension, transverse coupling, and mixed integration of eco-cycle industry chain, the mineral resources regional eco-cycle industry chain can be established, for instance, the industry chain of coal resource, one of mineral resources is as follows in Fig.1 [24].

3. Methodlogy

3.1 Green evaluation index system

3.1.1 Criterion

Based upon the characteristics of eco-cycle industry chain, the establishment of green index system of eco-industry chain should take natural ecological system regulation as the foundation, scientific development concept as the purpose, and circular economy theory and 3R principle as the construction concept [25]. It should follow the principles of systematic construction to ensure the rationality and scientificity of the indicators. Construction principles mainly include systematic scientificity and accuracy, effectiveness and comparability, stability and dynamic, operability, and qualitative and quantitative analysis., etc. [6, 26-28]. In this paper, it also follows the criteria in assessing the eco-industry chain, such as systematic scientificity and accuracy, effectiveness and comparability, combination of stability and dynamic, operability and combination of qualitative and quantitative principles and so on.

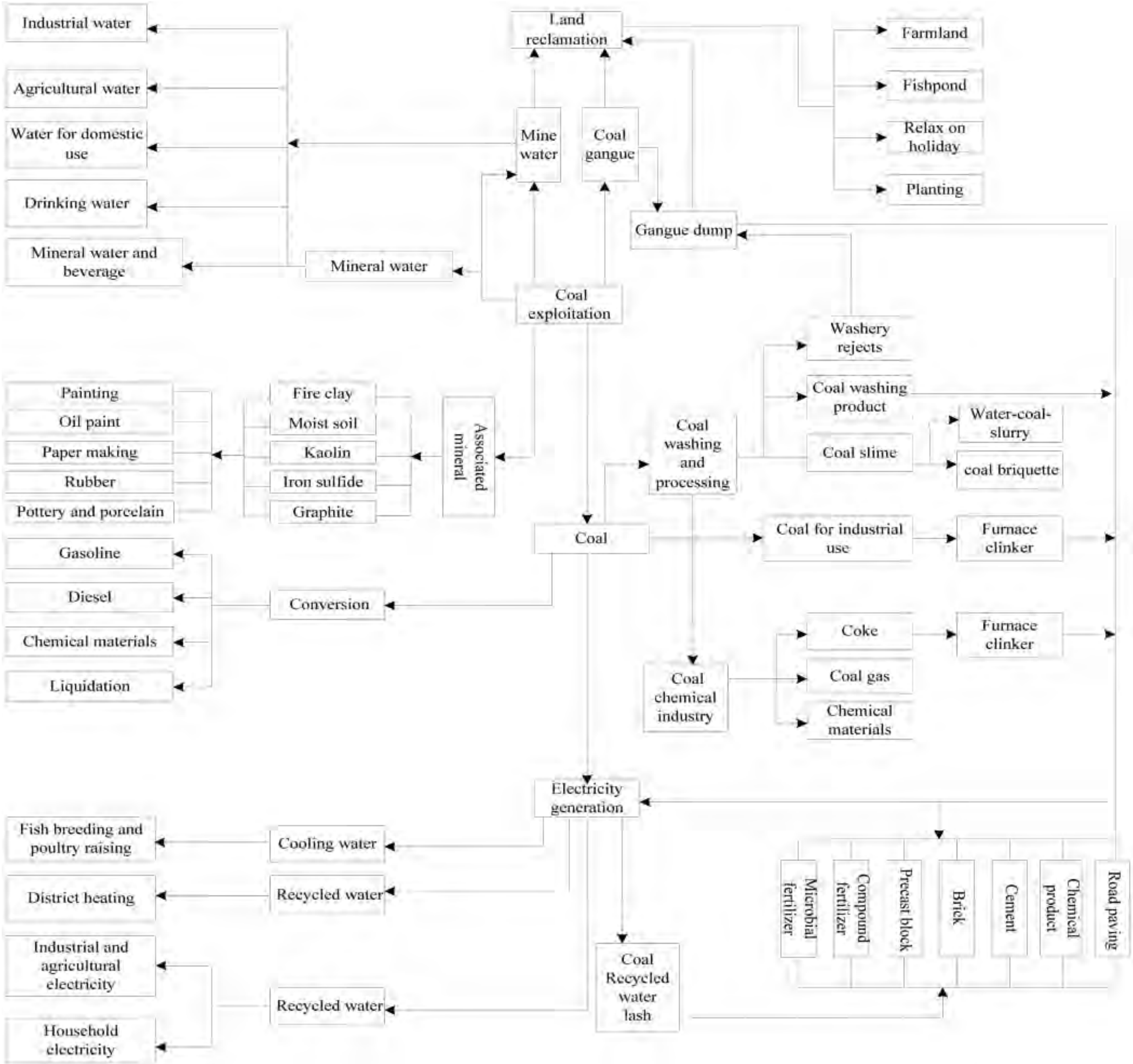


Fig.1 Eco-cycle industry chain of coal resource

3.1.2 Index system construction

(1) Selection of indicators: This paper checks some literatures about industrial evaluation index system, examines 316 indicators in total, finds out the indicators with higher frequency and considers the actual research situation in this paper to select a set of indicators which conforms to the concept of circular economy and green development. This set of indicators also relates to four aspects of economic operation, technology research and development, industry chain environmental impact, and ecological cycle innovation.

(2) Establishment of index hierarchy: This paper uses analytic hierarchy process to divide the indicators into three layers - target layer, criterion layer and index layer

(3) The target layer mainly expresses the overall development and basic idea of the company's eco-industry chain system. The criterion layer mainly divides the overall strategic development of eco-industry chain into four major indicators, including economic operation, technology research and development, industry chain environmental impact, and ecological cycle innovation, so as to learn about the specific implementation situation of eco-industry chain, internal and external environment treatment, and ecological development concept. The index

TABLE 1: THE LISTED INDICATORS

Target layer	Criterion layer	Index layer	References
Green evaluation index system of eco-cycle industry chain	Economic operation (A)	A1: Reduction rate of operating cost, taxes and surcharge	(Liu, 2012) (Zhang and Cui, 2016)
		A2: Reduction rate of three costs (management fees, financial cost and sales expense)	(Liu, 2012) (Zhang and Cui, 2016)
		A3: Operating revenue increasing rate	(Liu, 2012) (Zhang and Cui, 2016)
		A4: Net profit increasing rate	(Liu, 2012) (Zhang and Cui, 2016)
	R&D (B)	B1: R&D investment ratio	(Xu, Yu, and He, 2016) (Tang, et al, 2016) (Zhang and Cui, 2016) (Wang and Feng, 2012)
		B2: Proportion of R&D employees	(Xu, Yu, and He, 2016) (Zhang and Cui, 2016)
	Industry chain environmental impact (C)	C1: Increasing rate of pollution control investment (Wang, 2016)	(Xu, Yu, and He, 2016) (Wang and Feng, 2012)
		C2: Increasing rate of resource compensation fee	(Liu, 2012)
		C3: Pollutant emission controllable level	(Xu, Yu, and He, 2016) (Zhou, Wang, and Chi, 2016) (Sha and Ou, 2008) (Zhang, Qian, and Wang, 2016) (Xu, 2008)
		C4: Resource comprehensive recycling level	(Xu, Yu, and He, 2016) (Liu, 2012) (Tang, et al, 2016) (Wang and Feng, 2012)
		C5: Industry chain environmental risk prevention level	(Wang and Feng, 2012)
	Eco-cycle innovation (D)	D1: Green development concept	(Wang and Feng, 2012)
		D2: Ecological cycle information degree	(Wang, 2016)
		D3: Cycle technology level	(Xu, Yu, and He, 2016) (Wang, 2016)
		D4: Technical equipment level	(Xu, Yu, and He, 2016)
		D5: Condition of technically improved project	(Zhang and Cui, 2016)

layer centers around the criterion layer and selects a total of 16 indicators. The 16 indicators specifically reveal the company's operation, development and social responsibilities, which are shown in the framework of eco-industry chain index system (Table 1).

3.2 ENTROPY-TOPSIS EVALUATION MODEL

3.2.1 Entropy weight model

Entropy comes from thermodynamics. It is the measurement of uncertainty under the system state. And information is the measure of the system order degree. Of the two, they have equal absolute values but opposite signs. As early as 1948, Wiener and Shannong defined the uncertainty of the information source signal during communication process as information entropy, so as to express the relations between choice, uncertainty and random events and measure the useful information provided with obtained data, thus to determine the weight of the information [29-30].

Let us assume that q indicates the uncertainty of i th information (appearance probability), and there are m information, so the uncertainty (entropy) of m information is expressed as:

$$S = -k\sum_{i=1}^{m} q_i \ln q_i \quad \dots \quad (1)$$

In the formula, k is a positive constant. When the probability of each information is equal, $q_i = \frac{1}{m}$, the entropy takes the maximum value, and the weight index of the information is the minimum.

The concrete idea of entropy weight model is to calculate the information entropy of the index. The smaller the information entropy is, the lower the disorder degree of the information is and the greater the weight of information becomes. On the contrary, when the information entropy is greater, the disorder degree of the information is higher and the weight of information is smaller. The most important character of entropy weight method is to directly use information from decision matrix to calculate weight and excluding the subjective judgment of decision maker, so as to obtain a rather objective comprehensive evaluation result.

The detailed analysis steps are as follows:

(1) Assume that there are m evaluation targets and n evaluation indicators, the observed value of each evaluation object against each evaluation index is x_{ij}, to form the decision matrix:

$$Y = (x_{ij})_{m´n} \quad ... \quad (2)$$

If the difference value of index value x_{ij} of item x_j in the decision matrix (x_{ij}) is bigger, the index plays a more important role in comprehensive evaluation. If the index values of a certain index are all equivalent, the index has no effect in comprehensive evaluation. Thus the index can be excluded and Entropy-TOPSIS is introduced into the rest indicators.

(2) Normalize indicators. Calculate the relative weight p, of a certain capacity of no. i evaluation objects under no. j index. The equation is as follows:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (i = 1, 3, \cdots, m; j = 1, 2, \cdots, n) \quad ... \quad (3)$$

The normalized matrix is $(P_{ij})_{m´n}$

(3) Calculate the entropy value of No. j index

$$E_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij} \quad (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n) \quad ... \quad (4)$$

wherein, k is a constant, $k = \frac{1}{\ln^m} (0 \le E_j \le 1)$

(4) Calculate difference coefficient of no. j index

$$d_j = 1 - E_j \quad (j = 1, 2, \cdots, n) \quad ... \quad (5)$$

When E_j is bigger, the different coefficient d_j is smaller. When x_{ij} are all equivalent, $E_j = E_{max} = 0$, $d_j = 0$, and the weight is 0. It indicates that no. j index has no effect in the comprehensive evaluation and can be excluded. When E_j is smaller, the different coefficient d_j is bigger, indicating that no. j index plays a more important role in comprehensive evaluation.

(5) Calculate the weight

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (j = 1, 2, \cdots, n) \quad ... \quad (6)$$

The weight matrix is:

$$W = \begin{bmatrix} w_1 & 0 & \cdots & 0 \\ 0 & w_2 & \cdots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & w_n \end{bmatrix} \quad ... \quad (7)$$

3.2.2 TOPSIS model

TOPSIS (technique for order preference by similarity to ideal solution) is a multi-objective decision-making method and an ordering method close to the ideal solution. TOPSIS supposes an ideal scheme (solution) and a negative ideal scheme, and then separately determines the Euclidean distance between each solution and ideal solution and negative ideal solution, and finally selects the optimal solution that is closest to the ideal solution and farthest from the negative ideal solution.

TOPSIS proposes an ideal solution A^* and a negative ideal solution A^- based on the weighted normalized matrix, and determines the advantages and disadvantages of each solution. The specific steps are as follows:

(1) Build normalized matrix R

$$R = \left[r_{ij} \right]_{m \times n} \ddot{y} \left(r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \right) \quad ... \quad (8)$$

$(i = 1, 2 \cdots, m); (j = 1, 2, \cdots, n)$

(2) Construct weighted normalized matrix

$$V = R \circ M = \left[v_{ij} \right]_{m \times n} \; i = (1, 2, \cdots, m); j = (1, 2, \cdots, n) \quad ... \quad (9)$$

(3) Determine ideal solution and negative ideal solution. When the index value is benefit-oriented, the ideal solution is the maxin each row while negative ideal solution is the minimum. When the index value is loss-oriented, the ideal solution is min in each row while negative ideal solution is the max.

$$A^* = \left[\left(\min v_{ij} \middle| j \in J_1 \right), \left(\max v_{ij} \middle| j \in J_2 \right) \right]$$

$$= \left[v_1^*, v_2^*, ..., v_j^*, ..., v_n^* \right] (i = 1, 2, ..., m) \quad ... \quad (10)$$

$$A^- = \left[\left(\min v_{ij} \middle| j \in J_1 \right), \left(\max v_{ij} \middle| j \in J_2 \right) \right]$$

$$= \left[v_1^-, v_2^-, ..., v_j^-, ..., v_n^- \right] (i = 1, 2, ..., m) \quad ... \quad (11)$$

In the formula, J_1 is benefit-oriented index set, J_2 is loss-oriented index set, A^* is ideal solution, A^- is negative ideal solution.

(4) Calculate the distance

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \quad (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n) \quad ... \quad (12)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n) \quad ... \quad (13)$$

S_i^* indicates the distance between the evaluation object and ideal solution, S_i^- indicates the distance between the evaluation object and negative ideal solution.

(5) Calculate relative closeness coefficient

After getting S_i^* and S_i^-, relative proximity N_i could be calculated as follows:

$$N_i = \frac{S_i^-}{S_i^- + S_i^*} \ (i = 1, 2, \cdots, m) \ 0 \le N_i \le 1 \qquad \text{... (14)}$$

When $S_i^- = 0$, so N_i = 0,, that is, $A_i = A^-$ when no. i evaluation object A_i is negative ideal solution A^-, the closeness coefficient N_i is 0, when $S_i^* = 0$, so $N_i = 1$, $A_i = A^*$, that is, no. i evaluation object A_i is ideal solution A^*, the closeness coefficient N_i is 1.

(6) Rank the evaluation objects through the value of N_i.

4. Case study

4.1 Data sources

Taking consideration of the availability of data, this paper selects five companies including Chifeng Gold, Tianshan Textile, Western Gold, Tibet Mining and Yintai Resources as the object, and chooses data of 16 indicators from four aspects of economic operation, R&D, industry chain environmental impact, ecological cycle innovation via expert scoring method and analyzing their annual announcement to assess the state of eco-cycle industry chin, and finally figures out the relations between ecological cycle construction and company's economic efficiency and potential through a certain amount of analysis, as Table 2 shows.

4.2 Results and discussion

In order to eliminate the influence from each index dimension, the data are standardized, and the standardized data as shown in Table 2. And normalizing the data in Table 2, then we process the data by formula 4 and formula 6, finally the entropy H_j and weight w_j are obtained, the results are shown in Table 3. Based on Table 3, formula 12, formula 13 and formula 14 are used to figure out the ideal values, and through the ranks to work out the final results.

Table 2: Standardized data

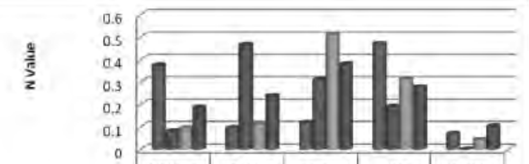
Item	Chifeng Gold	Tianshan Textile	Western Gold	Tibet Mining	Yintai Resources
A1	0.0000	0.2822	0.2787	0.1931	0.2461
A2	0.0000	0.2594	0.2898	0.2645	0.1863
A3	0.4959	0.0000	0.0310	0.4695	0.0036
A4	0.1735	0.0935	0.1464	0.5866	0.0000
B1	0.1357	0.1745	0.5348	0.1551	0.0000
B2	0.0304	0.6044	0.1577	0.2075	0.0000
C1	0.0816	0.0000	0.5082	0.4013	0.0088
C2	0.0657	0.0000	0.6470	0.2217	0.0657
C3	0.2170	0.1415	0.3774	0.2642	0.0000
C4	0.1515	0.1364	0.4091	0.3030	0.0000
C5	0.0000	0.3425	0.2740	0.3151	0.0685
D1	0.0000	0.4819	0.0602	0.4217	0.0361
D2	0.2985	0.0000	0.5522	0.1493	0.0000
D3	0.2414	0.0000	0.4138	0.0690	0.2759
D4	0.1458	0.0000	0.4375	0.3125	0.1042
D5	0.0000	0.1299	0.4545	0.2857	0.1299

Table 3: Entropy weight of indicators

Indicator		H_j	W_j
Economic operation	A1	0.8547	0.0320
	A2	0.8536	0.0323
	A3	0.5162	0.1067
	A4	0.6956	0.0671
Research and development	B1	0.7452	0.0562
	B2	0.6371	0.0797
Industrial environmental impact	C1	0.6388	0.0894
	C2	0.5945	0.0872
	C3	0.6048	0.0386
	C4	0.8249	0.0444
	C5	0.7985	0.0466
Eco-cycle innovation	D1	0.7886	0.0828
	D2	0.6245	0.0873
	D3	0.6044	0.0495
	D4	0.7754	0.0504
	D5	0.7714	0.0497

From Table 3, based on the internal comparison among indicators, in terms of industry chain environmental impact, we can learn that C1 and C2 share the same weight of about 0.08 and the weights of C3, C4, and C5 are around 0.04. Therefore, it can be speculated that companies has invested more into pollutant emission treatment and mineral resource exploitation than pollutant emission control, resource recycling and risk prevention. In the aspect of ecological cycle innovation, the weights of D1 and D2 are about 0.08, and the weights of D3, D4 and D5 are around 0.05. It can be deduced that companies has began to implement green development strategy, and has paid attention to the eco-cycle information degree, but they still needs to attach more importance on hardware equipment and technology. From the perspective of R&D, the weights of B1 and B2 are almost the same, and thus it can be speculated that companies begin to put into more effort in technology research and development. In the aspect of economic operation, the weights of A1 and A2 are about 0.03, the weight of A3 is 0.1 and A4 is 0.06. It shows that mining companies has achieved good operation benefit of low-cost and high-income. In view of indicators in each target layer, calculating their average, and the mean value of A is 0.0595, B is 0.0680, C is 0.0612, and D is 0.0639. The weights keep at a roughly equal, which indicate that the total investment from companies into R&D, industry chain environment and ecological cycle innovation are roughly equivalent.

To get the normalized weighted matrix according to the weights of each index and the normalized matrix, then calculate the close degree N between each evaluation object and positive ideal solution according to formula 11. Fig.2 and Fig.3 show the comprehensive close degree and the ranking of five companies in economic operation, R&D, industry chain environmental impact, and ecological cycle innovation. It can be seen that Western Gold, which has made achievements in industry chain environment construction and ecological cycle innovation, also achieves a lot in economic operation and R&D. On the contrast, Yintai Resources falls behind the other companies in industry chain environment construction and ecological cycle innovation, and its work on economic operation and R&D also ranks behind the other companies. Therefore, it is not difficult to speculate that the intensity of input in environmental protection is closely related to the company's economic benefits.



	Chifeng Gold	Tianshan Textile	Western Gold	Tibet Mining	Yintai Resources
Economic Operation	0.3766	0.098	0.1191	0.4723	0.0706
Research and Development	0.0806	0.467	0.3114	0.1913	0
Industrial Environmental Impact	0.096	0.1148	0.5146	0.3147	0.0448
Eco-cycle Innovation	0.1879	0.2404	0.3807	0.2787	0.1052

Fig.2 N value of close degree between each evaluation object and positive ideal solution

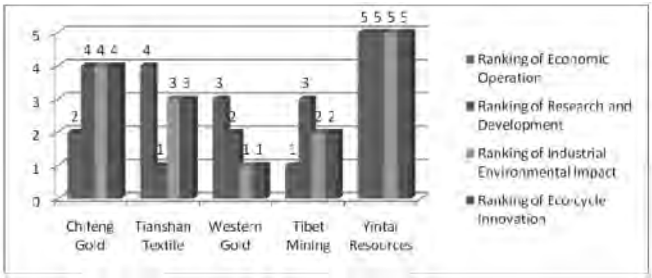


Fig.3 Ranking of each evaluation object and positive ideal solution

Usually, green evaluation indicators are divided into five ranks: lower stage ($N<0.2$), primary stage ($0.2<N<0.4$), middle stage ($0.4<N<0.6$), relatively advanced stage ($0.6<N<0.8$), and the advanced stage ($0.8<N<1.0$). In Fig.3, it can be found that a company's industry chain environment construction and ecological cycle innovation are positively related to economic operation and R&D. We can vertically analyze these items in detail.

(1) In terms of economic operation, Tibet Mining ranks the first of five companies, while Yintai Resources the last. In addition, N value of Tibet Mining reaches 0.4723 and Yintai Resources is 0.0706, which shows that the performance of Tibet Mining in recent years is far more better than that of Yintai Resources.

(2) In the aspect of technology research and development, Tianshan Textile takes the leading position, while Yintai Resources still the last. It means that the good or bad situation of economic operation may be related to capital investment in technology. Therefore, Yintai Resources with an insufficient cash flow falls behind the other companies.

(3) In the aspect of industry chain environmental impact and ecological cycle innovation, Western Gold ranks the first and Yintai Resources the last. However, Chifeng Gold, which ranks the second in economic operation, only takes the fourth place. Tibet Mining comes in second while it takes the first place in economic operation previously; Tianshan Textile, which ranks the fourth in economic operation previously, now takes the third place. This shows that economic operation and R&D cannot improve the construction of industry chain ecological cycle, and only when the construction of industry chain and ecological cycle achieves remarkable success, the economic operation efficiency will be improved. Therefore, industry chain environment construction and ecological cycle innovation affects the company's economic operation and technology research and development progress.

At the same time, we can analyze the close degree N of the five companies horizontally.

(1) N value of economic operation of Chifeng Gold reaches 0.3766, much higher than that of the other aspects, which indicates that economic operation is Chifeng Gold's advantage.

(2) The R&D of Tianshan Textile's ranks high, and its N value is 0.4670, revealing that Tianshan Textile's main competitiveness lies in technology development.

(3) Industry chain environmental impact of Western Gold is the best with N value reaching 0.5146, and N value of its ecological cycle innovation reaches 0.3807, showing that Western Gold pays more attention to ecological development.

(4) Tibet Mining, like Chifeng Gold, has done the best job in economic operation.

(5) Yintai Resources is relatively weak in competitiveness compared to other four companies. The N value of its ecological innovation ranks the first among the other aspects but reaches only 0.1052.

In addition, Table 4 shows the close degree of Western Gold reaches the optimal level while Yintai Resources takes the last place. According to such N value, the construction of mineral resource eco-cycle industry chain of Western Gold, Tibet Mining, Tianshan Textile and Chifeng Gold still lies in initial stage, while N value of Yintai Resources is less than 0.1, and its effort in construction of eco-cycle industry chain construction is far from enough.

TABLE 4: RANKING OF CLOSE DEGREE FOR EACH EVALUATION OBJECT

Listed company	S+	S-	SUM	N	Ranking
Chifeng Gold	0.2249	0.0638	0.2888	0.2211	4
Tianshan Textile	0.2340	0.0675	0.3015	0.2240	3
Western Gold	0.1883	0.1051	0.2935	0.3582	1
Tibet Mining	0.1846	0.0924	0.2770	0.3335	2
Yintai Resources	0.2561	0.0202	0.2763	0.0730	5

Therefore, through the vertical, horizontal and comprehensive analysis on the data, we can draw the conclusion that the construction of eco-cycle industry chain by listed companies in China's autonomous region lies in primary stage, and to successfully build an eco-cycle industry chain contributes to company's operation and development.

5. Conclusions

Through above empirical analysis, the Western Gold for its comprehensive good economic operation, R&D, the industry chain environment impact and ecological circulation innovation to ranks the first, which is relative to other listed companies on the whole to achieve the optimal level. Tibet mining also for its nice environmental governance and green economy to result in the second, and Tianshan Textile with better technology research and development in the third, Chifeng Gold's economic operation effect is fine but the green innovation cycles and environmental governance is slightly behind, so it ranks the No.4, but Yintai Resources with poor development in the four aspects to rank in the bottom. From the point of view of the overall value of N, even though the Western Gold is at the optimal level of the construction of the ecological circulation industry chain, the N value is not more than 0.4, while Yintai Resources of the value of N is less than 0.1, therefore , the listed mining companies in China's autonomous region for the construction of ecological industry chain are at low initial stage, some companies even still are given priority to with the traditional extensive development, and economic efficiency is not high, so the autonomous region of China's mineral resources listed companies need the transformation and upgrading. Therefore, some suggestions for the mineral resources listed companies in autonomous regional to improve present situation and achieve the transformation of industrial chain would be as follows:

(1) Establish the green development concept of eco-cycle industry chain based on the current situation of environmental pollution. Through the data processing, the weight of green development is higher than the other index, therefore, to establish green development concept is good for the future development of the enterprises, and the overall optimization have positive effects. Mineral exploitation has always been one of the main sources of Chinese economy, but the problems caused by environmental pollution can not be ignored. Most listed companies have begun to explore the new concept of ecological cycle development [31], strive to optimize the allocation of resources, improve resource utilization, and develop a new sustainable green development of low-consumption and high-growth.

(2) Increase the R&D input of environmental protection. After building a complete ecological cycle system, the first thing companies should do is to throw themselves into the construction of eco-cycle industry chain immediately. The improvement of environmental quality requires innovation of environmental protection technology. However, it is unrealistic to just wait for the new environmental protection technology, therefore, it is necessary to establish a reasonable environmental policy mechanism to marketize the environmental technology, so as to internalize the external effect of environmental protection technology innovation. Companies need to adjust capital operation scheme, increase investment in environmental R&D, to achieve the companies' eco-cycle goals and realize the transition of industry chain successfully.

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