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Research on the application of VIKOR based on fuzzy comprehensive evaluation model in industrial enterprises

Liu Na[1]

[1]China National Institute of Standardization, Beijing 100191, China

Abstract. In this paper, through the innovative use of the AHP entropy coupling weight method to determine the index weight, the evaluation results of industrial enterprises (taking coal mine as an example) are divided into three world-class levels domestic advanced, and domestic general, and then the index regions of each evaluation index corresponding to the evaluation level are divided. On this basis, VIKOR fuzzy comprehensive evaluation is selected to carry out empirical research in industrial enterprises, and finally, the effective evaluation of industrial enterprises is realized, aiming at improving the production efficiency of industrial enterprises in view of the shortboard.

1 Introduction

China's industry has a good foundation for development and is constantly facing new challenges. During the "14th five-year plan" period, it is necessary to timely adjust the orientation of industry in the national economy according to the changes of development conditions and environment, further clarify the development tasks and key areas of industrial enterprises, cultivate and strengthen new competitive advantages of industry, and accelerate industrial modernization at a higher level. Therefore, mining the evaluation methods of industrial enterprises and finding out the shortboard is very important for improving the production efficiency of industrial enterprises and accelerating the development of industrialization.

2 The basic principle of fuzzy comprehensive evaluation model based on VIKOR

A comprehensive evaluation is the application of scientific and feasible evaluation methods, through the analysis and evaluation of various influencing factors, and finally, determine the evaluation level. In this paper, through the innovative use of the AHP-Entropy Coupling Weight Method to determine the index weight, taking coal enterprises as an example, the evaluation results are divided into three world-class levels domestic advanced, and domestic general, and then the index regions corresponding to the evaluation level of each evaluation index are divided. On this basis, VIKOR multi-attribute evaluation method is selected for a comprehensive evaluation, and finally, the effective evaluation of industrial enterprises is realized.

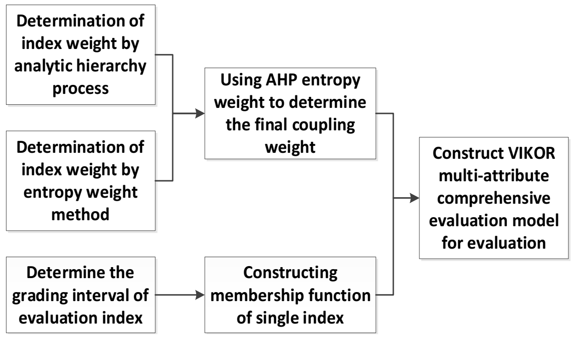

Fig1 The fuzzy comprehensive evaluation process based on VIKOR

3 Weight determination of index system

3.1 Analytic hierarchy process (AHP)

Analytic hierarchy process (AHP) was proposed by Professor A.L. Saaty of the University of Pittsburgh in the 1970s. This method is suitable for analyzing complex systems with multiple objectives and criteria. It can combine qualitative analysis with quantitative analysis, and is easy to use and operate, and is suitable for many fields.

(1) Construct a judgment matrix

List the names of each index in the judgment matrix, and the values in the judgment matrix reflect the relative importance between the index of this layer and the related index.

Suppose that the factor Ak in layer a is the same as the factorB1, B2, ⋯, Bn, the judgment matrix is shown in Table 1.

* Corresponding author: 974345816@qq.com

Tab. 1 The judgment matrix table of A_k

A_k	B_1	B_2	⋯	B_n
B_1	b_{11}	b_{12}	⋯	b_{1n}
B_2	b_{21}	b_{22}	⋯	b_{2n}
⋯	⋯	⋯	⋯	⋯
B_n	b_{n1}	b_{n2}	⋯	b_{nn}

b_{ij} is the relative importance of B_i to B_j in A_k, b_{ij} takes 1, 2, 3, ……, 9 and their reciprocal.

Tab. 2 The meaning of each numerical scale

b_{ij}	Meaning
1	B_i is as important as B_j
3	B_i is slightly more important than B_j
5	B_i is important than B_j
7	B_i is more important than B_j
9	B_i is extremely important than B_j
2,4,6,8	The intermediate value of the above adjacent judgment

(2) Obtain the eigenvalue through the judgment matrix, and obtain the corresponding eigenvector according to the eigenvalue. Finally, carry out the consistency test to judge whether the result is accurate.

①Calculate the product of elements in each row of judgment matrix Mi

$$M_i = \prod_{j=1}^{n} b_{ij} \quad (i=1,\ 2,\ \dots,\ n) \tag{1}$$

②Calculating the n-th root of Mi

$$\bar{W}_i = \sqrt[n]{M_i} \tag{2}$$

③Normalization of vector

$$\bar{W} = [\bar{W}_1, \bar{W}_2, \cdots, \bar{W}_n]^T$$

$$W_i = \frac{\bar{W}_i}{\sum_{i=1}^{n} \bar{W}_i} \tag{3}$$

④ According to AW=Kmax W, find the largest eigenvalue and eigenvector

(3) Consistency test

①Calculate consistency index CI= $\frac{\lambda_{\max} - n}{n-1}$

② Find out the corresponding average random consistency index RI

③Calculate consistency ratio CR=CI/RI

When CR<0.1, consistency test is acceptable

Tab. 3 Value table of RI

Order n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1,45

In the specific application, use the Delphi method to obtain the original data to construct the judgment matrix, and then calculate and determine the weight according to the steps of the analytic hierarchy process.

3.2 Entropy weight method

Assuming that the enterprise to be evaluated is $A_i(i=1,2,\cdots,m)$, construct the evaluation index matrix U according to the existing evaluation index system $C_j(i=1,2,\cdots,n)$;

$$U=(u_{ij})_{mn} = \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ u_{m1} & u_{m2} & \cdots & u_{mn} \end{bmatrix}_{m\times n} \tag{4}$$

Among them, uij is the original data evaluation value of the i-th evaluation object under the j-th evaluation index.

① Normalize the data and calculate the index value proportion FIJ of the i-th evaluation object under the j-th evaluation index

$$f_{ij} = \frac{u_{ij}}{\sum_{i=1}^{m} u_{ij}} (i=1,2,3,\dots,m; j=1,2,3,\dots n) \tag{5}$$

② Calculate the entropy of the j-th index e_j

$$e_j = -\frac{1}{\ln m}\sum_{j=1}^{n} f_{ij} \ln(f_{ij}),\ e_j > 0 \tag{6}$$

$$If\ \ f_{ij} = 0, \quad then\ \lim_{f_{ij}\to 0} f_{ij} \ln f_{ij} = 0$$ 。

③ Calculate the entropy weight UJ of the j-th index uj

$$u_j = \frac{1-e_j}{\sum_{j=1}^{n}(1-e_j)} (j=i,2,3,\dots n) \tag{7}$$

3.3 AHP - Entropy Weight coupling weight method

The analytic hierarchy process (AHP) gives weight to the index by experts' subjective scoring, which has certain subjective randomness; Entropy weight method is an objective method to give index weight value. It fully excavates the information carried by the original data and has stronger objectivity. However, this method lacks the experience of experts and the opinions of decision-makers. The index weight value calculated by this method may not be consistent with the actual situation. In practical application, whether only using AHP or entropy weight method, it may lead to the deviation of evaluation results, which is not in line with the actual situation. This paper combines the subjective weight Ci obtained by the analytic hierarchy process with the objective weight uj obtained by entropy weight method and then coupling the two indexes to obtain the composite weight λi of the lowest index relative to the highest one.

$$\lambda_i = aC_i + (1-a)u_j\ ,\ (0 \le a \le 1) \qquad (8)$$

It can be seen from the formula that when a is different, the composite weight is also different. When a = 0, the composite weight corresponds to the objective weight obtained by the entropy weight method; when a = 1, the composite weight corresponds to the subjective weight obtained by AHP.

4 VIKOR multi-attribute evaluation method

In this study, VIKOR multi-attribute evaluation method is used to determine the priority of the evaluation objects and compare the evaluation results of the comprehensive evaluation models of various industrial enterprises to judge whether the results are consistent. If they are consistent, it shows that the comprehensive evaluation model established in this study is effective.

The evaluation steps of the VIKOR multi-attribute evaluation method are as follows,

(1) Determine index weight

(2) Index dimensionless processing: because the world-class coal mine evaluation indexes have different dimensions and orders of magnitude, it is necessary to carry out dimensionless processing for each index data first.

$$y_i = x_i / \sqrt{x_1^2 + x_2^2 + \cdots + x_n^2} \qquad (9)$$

(3) For the above-standardized processing matrix, the positive and negative ideal values of each index are calculated, that is, the maximum and minimum values of each evaluation index are found.

$$f_i^* = [(\max_j f_{ij} |\ i \in I_1), (\min_j f_{ij} |\ i \in I_2)] \qquad (10)$$

$$f_i^- = [(\min_j f_{ij} |\ i \in I_1), (\max_j f_{ij} |\ i \in I_2)] \qquad (11)$$

(4) Calculate the optimal solution Sj and the worst solution Rj (j=1,2··n)

$$S_j = \sum_i^n \lambda_i (f_i^* - f_{i,j}) / (f_i^* - f_i^-) \qquad (12)$$

$$R_j = \max[\lambda_i (f_i^* - f_{i,j}) / (f_i^* - f_i^-)] \qquad (13)$$

Among these, λi is the index weight, Sj is the weighted distance from the j-th evaluation value to the positive ideal solution, and Rj is the weighted distance from the j-th evaluation value to the negative ideal solution.

(5) Calculate the VIKOR Qj of evaluation

$$Q_j = v(S_j - S^*) / (S^- - S^*) + (1-v)(R_j - R^*) / (R^- - R^*) \qquad (14)$$

Among $S^* = \min_j S_j$, $S^- = \max_j S_j$; $R^* = \min_j R_j$, $R^- = \max_j R_j$. S* is the maximum utility in the evaluation object, R* is the minimum regret in the evaluation object, and v represents the "most criteria" strategy weight, also known as the maximum group utility weight. To maximize group utility and minimize individual regret, we set v as 0.5.

(6) Determine the priority of evaluation objects

According to the values of Si, Ri and Qi the order of evaluation objects is determined. Taking A1 as the best coal mine in comprehensive development, the smaller the Q, S, and R values, the higher the ranking. The sorting principle is as follows,

Condition 1, $Q(a_2 - a_1) \ge 1/(J-1)$, a2 is the suboptimal scheme ranked by Q-value;

Condition 2, the s-value or R-value of a1 comes first;

If one of the above conditions is not satisfied, then

(1) If condition 2 is not satisfied, a1 and a2 are both compromise units;

(2) If condition 1 is not satisfied, then a1, a2,……, ar is a compromised unit, where ar satisfies $Q(a_r) - Q(a_1) \ge 1/(J-1)$

5 Application of VIKOR based fuzzy comprehensive evaluation model in industrial enterprises

In this study, Shendong group as a subordinate coal mine as the evaluation object. As an advanced coal mining enterprise in China, Shendong group can represent the development level of China's coal industry. The selection of first-class coal mines within the group is conducive to the learning and imitation of other domestic coal mining units. According to the principle of data availability, the production data of Daliuta mine (M1), Bulianta mine (M2), Yujialiang mine ((M3), Shangwan mine ((M4), Wulanmulun mine ((M5), Baode mine ((M6), Halagou mine ((M7), Shigetai mine ((M8), Buertai mine ((M9), Cuncaota No.1 mine ((M10) and Cuncaota No.2 mine ((M11) in 2020 are taken as the evaluation statistics Elephant.

According to the evaluation steps of the VIKOR multi-attribute evaluation method, Shendong group samples are evaluated. The evaluation process is as follows,

(1) Dimensionless processing

Using $y_i = x_i / \sqrt{x_1^2 + x_2^2 + \cdots + x_n^2}$ to calculate the actual evaluation value of the world-class coal mine evaluation system;

(2) Calculate the positive and negative ideal value of the index

Tab. 4 Positive ideal solution and negative ideal solution

Index	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
f*	0.327	0.33	0	0	0.043	0	0.345	0.351	0.375	0.35	0.315
f−	0.152	0.036	1	1	0.967	0.871	0.127	0.17	0.22	0.153	0.29

Index	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}
f*	0.511	0.457	0.453	0.438	0.465	0.121	0.411	0.480	0.419	0.332	0.314
f⁻	0.095	0.113	0.163	0.144	0.166	0.486	0.119	0.061	0.227	0.199	0.278
Index	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}
f*	0.319	0.319	0.337	0.337	0.32	0.316	0.321	0.332	0.325	0.333	0.338
f⁻	0.286	0.280	0.144	0.263	0.28	0.264	0.265	0.247	0.253	0.247	0.262
Index	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{39}	C_{40}	C_{41}	C_{42}	C_{43}	C_{44}
f*	0.325	0.305	0.116	0.106	0.379	0.314	0.596	0.302	0	0	0.354
f⁻	0.281	0.296	0.624	0.487	0.189	0.251	0.000	0.296	0.559	0.483	0.242
Index	C_{45}	C_{46}	C_{47}	C_{48}	C_{49}	C_{50}	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}
f*	0.271	0.343	0.303	0.346	0.404	0.370	0.377	0.346	0.405	0.329	0.322
f⁻	0.325	0.219	0.297	0.222	0.202	0.187	0.184	0.229	0.141	0.154	0.171
Index	C_{56}	C_{57}	C_{58}	C_{59}	C_{60}	C_{61}	C_{62}	C_{63}	C_{64}	C_{65}	
f*	0.338	0.334	0.365	0.327	0.317	0.56	0.302	0.332	0.318	0.304	
f⁻	0.152	0.134	0.234	0.157	0.127	0.093	0.299	0.152	0.273	0.289	

(3) Calculate the relative closeness s and R values of each coal mine to the positive ideal solution and the negative ideal solution, and then calculate the Q value and sort it as shown in Table 5.

Tab. 5 The value of R,S,Q and their rank ordering

Evaluation unit	S	R	Q	Sort by Q	Sort by S	Sort by R
Daliuta mine M_1	0.127	0.014	0.000	1	9	1
Bulianta mine M_2	0.213	0.016	0.097	2	10	2
Yujialiang mine M_3	0.182	0.025	0.152	3	6	5
Shangwan mine M_4	0.347	0.023	0.272	4	7	3
Wulanmulun mine M_5	0.707	0.067	1.000	11	1	11
Baode mineM_6	0.552	0.043	0.640	10	3	10
Halagou mine M_7	0.372	0.024	0.306	5	5	4
Shigetai mine M_8	0.428	0.033	0.439	6	8	6
Buertai mine M_9	0.406	0.039	0.477	7	11	9
Cuncaota No.1 mine M_{10}	0.477	0.034	0.495	8	4	7
Cuncaota No.2 mine M_{11}	0.543	0.037	0.578	9	2	8

(4) Determine the order of evaluating coal mines

After the calculation of VIKOR comprehensive evaluation value, according to the two conditions in the ranking principle, 11 coal mines are evaluated and ranked as world-class coal mines. Among them, the number of evaluation objects is 11, so the calculable threshold value is $1/(J-1)=1/(11-1)=0.1$. Finally, the evaluation results of the coal mine are as follows

M1> M2，M3> M4，M7> M8，M9 ，M10> M11，M6 > M5

Daliuta mine (M1) has the best comprehensive evaluation result after compromise, followed by Bulianta mine (M2) and Yujialiang mine (M3), Shangwan mine (M4) and Halagou mine (M7), Shigetai mine (M8), and bultai mine (M9), Cuncaota No.1 mine (M1), Cuncaota No.2 mine (M11) and Baode mine (M6), and Ulan Mulun mine (M5) is the evaluation result. The worst of all. Among them, M2 and M3 are relatively backward compared with M1, and better than M4 and M7; M4 and M7; M8, M9 , and M10; M11 and M6 are the same.

6 Conclusion

In this paper, an AHP entropy weight coupling weight method based on the analytic hierarchy process and entropy weight method is proposed. This method avoids the defects caused by the single subjective weight determination method only using the analytic hierarchy process and the single objective weight determination method using the entropy weight method. The combination of the two methods, subjective and objective, leads to higher reliability of weight. On this basis, a fuzzy comprehensive evaluation model based on VIKOR is proposed to provide theoretical support for enterprise evaluation. Taking a coal mine as an example, empirical research is carried out to ensure the scientificity and operability of the model.

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