Research on Supplier Evaluation Method Based on Improved Fuzzy Evaluation Model

Rui Ma*[a], Zhong Yang[b], Zhuowen Li[c], Xiaojie Zhang[d], Lingyun Mao[e]

1948851284@qq.com*[a], workchen1996@outlook.com[b], ecxb400063@163.com[c], cwzaawn004@163.com[d], ckfey52051@163.com[e]

Southern Power Grid Supply Chain (Yunnan) Co.,Ltd, Kunming, Yunnan 650206, China

Abstract: In order to effectively improve the effectiveness and rationality of the evaluation of power material suppliers, a supplier evaluation model is designed based on the improved fuzzy comprehensive evaluation method. Firstly, corporate social responsibility dimension is introduced on the basis of existing supplier evaluation, and a comprehensive evaluation index system containing organizational factors, product factors, supply factors, after-sales factors and social responsibility is constructed. Secondly, in order to avoid the insufficiency of subjective factor assignment in the traditional fuzzy comprehensive evaluation method, hierarchical analysis and factor analysis are adopted to improve the calculation of its weights. Finally, the applicability of the evaluation model is verified by case analysis, which can provide reference significance for the bidding management and operation decision-making of electric power companies.

Keywords: fuzzy comprehensive evaluation method; hierarchical analysis method; factor analysis method; power supplier; social responsibility

1 Introduction

With the continuous expansion of the scale of power grid construction and the gradual development of smart grid construction, the material procurement work and material intensive management of power grid enterprises has put forward higher requirements, in order to further enhance the efficiency and effectiveness of the company's operational efficiency, strengthen the ability to ensure the supply of materials and improve the level of intensive management of material resources, supplier behavior analysis and comprehensive evaluation of suppliers has a certain degree of practical significance [1].

As a pillar industry of the national economy, electric power enterprises shoulder the heavy responsibility of fulfilling social responsibility, and the construction of its indicator system should be based on the traditional supplier life cycle, and comprehensively consider its social responsibility dimension indicators [2]. In addition, due to the fact that the suppliers of electric power enterprises are characterized by a wide variety of types, wide distribution of industries, and large differences in suppliers, resulting in increased difficulty in supplier relationship management. Existing theoretical research focuses more on the construction of the index system and the use of comprehensive evaluation method for the comprehensive evaluation of suppliers, but based on the social responsibility perspective on the evaluation of electric power enterprise suppliers research is still relatively small [3], the current State Grid has already formulated the

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evaluation index system for each type of material, but failed to realize the effective linkage between the evaluation results and the bidding management, so it is necessary to build a perfect supplier comprehensive evaluation model [4].

At present, more research work has been done around supplier evaluation at home and abroad, including not only the construction of evaluation index system, but also the innovation of evaluation methods, which mainly involves multivariate discriminant analysis (MDA), fuzzy comprehensive evaluation method, gray clustering trigonometry, neural network, and support vector machine, etc [5-9]. Literature [5] conducted a credit scoring study on Tanzanian commercial banks using MDA, but the assumptions of its independent variables are difficult to fulfill in practice. Literature [6] introduced LRA into the field of credit score line assessment for the first time, which effectively solved the problem of categorizing qualitative indicators, however, there are deficiencies in its treatment of quantitative indicators. Literature [7] used MDA to assess the risk of bank credit, but the independent variables of multivariate discriminant analysis have strict assumptions on the premise, and its generalization ability in reality is poor. Literature [8] proposes a smart grid construction evaluation method based on principal component clustering to analyze the value of principal component analysis and factor loading matrix clustering analysis, and adopts a horizontal comparison strategy to reduce the complexity of the problem, and verifies the effectiveness of the method. Literature [9] constructs SDN evaluation index system under the new electricity market pattern, and proposes a comprehensive evaluation model based on collaborative group decision-making, adopting a combination of weighted average operator to agglomerate individual preferences, and realizing the coherence between the interests of the participating individuals and the group through the dynamic adjustment of the information interaction and the weight of the opinions, and the method has a certain degree of dependence on the decision-making subject type and distribution.

Throughout the previous research, it can be found that they more often use clear and transparent, easy to quantify data for comprehensive evaluation of suppliers, and the results ignore the ambiguity and uncertainty in supplier evaluation. In comparison, the fuzzy comprehensive evaluation method introduces fuzzy mathematical ideas into the comprehensive evaluation, which has the characteristics of clear results and strong systematicity, and better solves the problem of quantification of fuzzy indexes, as well as the problem of index degree of affiliation measure, which is of good applicability for the comprehensive evaluation of electric power suppliers. In view of this, this paper starts from the actual status quo of electric power supplier management, introduces the factor of corporate social responsibility, designs the supplier comprehensive evaluation index system, and constructs the electric power supplier evaluation model based on the improved fuzzy comprehensive evaluation method, and finally verifies the validity and feasibility of the model through the analysis of the arithmetic example.

2. Comprehensive supplier evaluation indicator system

2.1 Principles of construction of the indicator system

Electric power enterprise supplier evaluation for the electric power company supplier management, bidding management and materials management and other aspects of the crucial, comprehensive evaluation of supplier indicators should reflect the comprehensive strength of the supplier, the selection of indicators should follow the "comprehensiveness, typicality, independence, practicality" and other principles.

(1) Comprehensiveness. Requirements for the selection of indicators should be from the multiple dimensions of supplier behavior, based on the evaluation objectives of a comprehensive search for supplier indicators, reflecting the characteristics of the supplier and the comprehensive strength of the information.

(2) Typicality. Supplier evaluation often involves more indicators, all the selection will be too redundant, so the selection of indicators should have a certain degree of typicality, on behalf of the characteristics of a cluster of suppliers.

(3) Independence. Refers to the selection of indicators should be independent of each other, can independently reflect the amount of information on a particular characteristic of the supplier, if the indicators are related to easily cause information loss and information overlap.

(4) Practicality. Refers to the selection of indicators should have a certain practical significance, the reality of supplier management has a certain guiding significance, the selection of indicators should be from the current situation of supplier management, to find the key indicators affecting supplier evaluation.

2.2 Design of the evaluation indicator system

The construction of evaluation index system is an important premise of the comprehensive evaluation of power suppliers, the current power supplier evaluation index system is mainly based on supply chain management and supplier behavior theory construction, literature [10] combined with the State Grid power material procurement and supplier management of the actual requirements, from the various aspects of supply chain management to build a power supplier evaluation index system, improve the effectiveness of supplier evaluation. The introduction of corporate social responsibility dimensions in the literature [11] constructed a new evaluation index system for enterprises, reflecting the importance of social responsibility assessment for traditional large pillar enterprises. On this basis, this paper introduces the corporate social responsibility dimension, comprehensively considers the five factors of organizational factors, product factors, supply factors, after-sales factors and social responsibility of electric power enterprise material suppliers, and constructs the corresponding secondary subdivision indexes through the expert research method and brainstorming method, and the corresponding index system is shown in Fig.1.

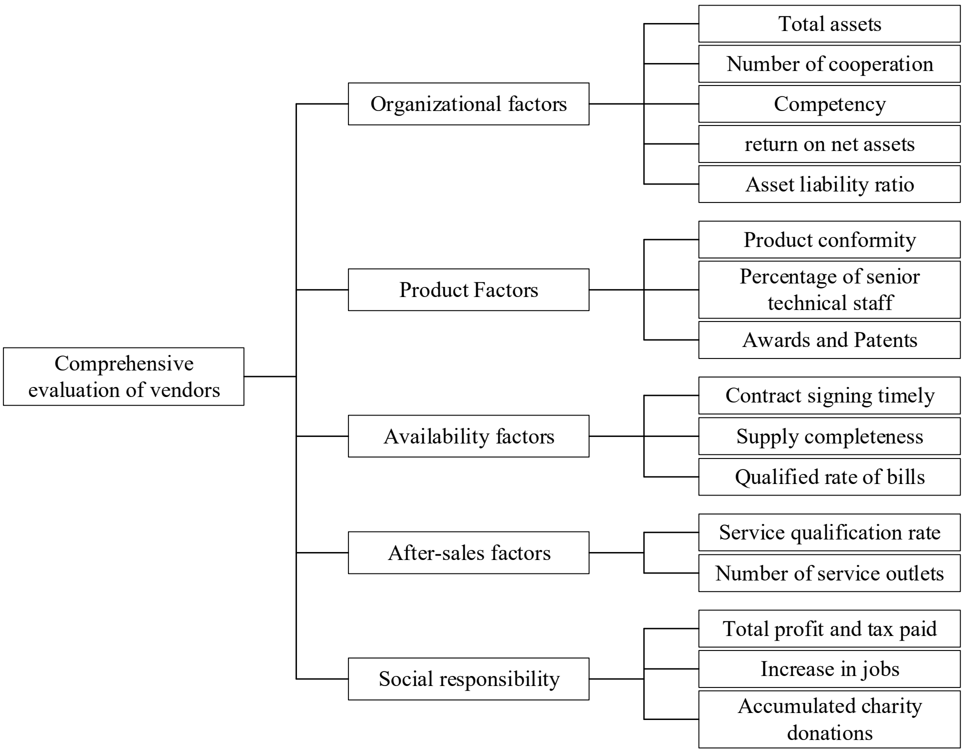

Fig.1 Supplier comprehensive evaluation index system

(1) Organizational factors. Supplier organizational factors mainly include the basic situation of the enterprise, qualification ability, profitability, financial risk and other aspects of the indicators, a comprehensive reflection of the supplier organization's own comprehensive strength, this paper selects the total assets, the number of times of cooperation, qualification scores, return on net assets, gearing ratio of the five sub-indicators to reflect the supplier's organizational factors, which qualification scores through the sum of the single qualification scores.

(2) Product factors. Mainly involves two aspects of product quality and R & D capability, product quality selection supplier product sampling pass rate, product R & D capability through the proportion of senior technical staff and awards and patents to reflect the score.

(3) Availability factors. From the contract signing, supply capacity, fulfillment and other dimensions of the selection of sub-indicators, including contract signing timeliness, supply integrity, three single (distribution and acceptance of single, put into operation single, quality assurance single) qualified rate and other indicators, supply integrity indicates the actual supply volume and the contract should be completed within the volume of the ratio.

(4) After-sales factors. After-sales factors reflect the supplier's after-sales service capabilities, mainly contains service pass rate and the number of service outlets two indicators, service pass rate indicates the number of good service and the total number of times the ratio of the total number of service outlets to a certain extent the supplier can reflect its after-sales service capabilities.

(5) Social responsibility. As a large-scale energy enterprise related to the lifeblood of the national economy, electric power enterprises have the right and obligation to take the lead in fulfilling their social responsibility, which in turn promotes the forward development of the whole society. In this paper, we have selected the total amount of profits and taxes paid, the number of jobs increased, and the value of charitable and public welfare expenditures and other sub-indicators.

3 Supplier evaluation model

3.1 Improvement of fuzzy comprehensive evaluation method basic idea

In order to understand the problem of quantification of deterministic indexes and index affiliation degree measure, fuzzy mathematical theory is introduced and fuzzy comprehensive evaluation method is used for supplier evaluation analysis. Fuzzy mathematical theory was firstly put forward by the American automatic control expert L. A. Zadeh for studying the fuzzy phenomenon of things. Fuzzy comprehensive evaluation method is based on fuzzy mathematics, for the situation that the conceptual boundaries of things are not clear, the concept of affiliation is introduced, the concept of evaluation indexes of things is quantified, and the comprehensive evaluation of the target is evaluated from multiple dimensions [12].

The improved fuzzy comprehensive evaluation method is based on the fuzzy comprehensive evaluation theory and the idea of comprehensive assignment method, improves the traditional weight calculation method, takes into account the subjectivity and objectivity of the index calculation in the process of assignment, adopts the hierarchical analysis method and the factor analysis method to calculate the comprehensive weight vector of the indexes, and carries out the process of supplier evaluation based on the fuzzy comprehensive evaluation method. The following section firstly introduces the calculation of the weight vector based on AHP+FA in the improved algorithm, and secondly introduces the specific steps of the improved fuzzy comprehensive evaluation method in detail.

3.2 AHP+FA based integrated weight vector determination

The traditional fuzzy comprehensive evaluation method uses hierarchical analysis method (AHP) to calculate the weights of indicators, and the assignment process has strong subjectivity, which does not reflect the information carried by the data itself. In view of this, the article takes into account the subjectivity and objectivity of the weights of indicators, and introduces the factor analysis (FA) on the basis of the AHP to calculate the objective weights of the indicators, i.e., using the AHP + FA to calculate the comprehensive weights of indicators, effectively improving the accuracy and applicability of the model. The specific weight calculation process is shown below:

(1) Subjective weight calculation

1) Construct progressive hierarchical index system. Analyze the evaluation indexes of power material suppliers, and get the supplier evaluation index system with progressive hierarchical characteristics.

2) Construct judgment matrix. Using the expert scoring method, the importance of the indicators

belonging to the same level is compared with the importance of the corresponding upper level indicators, and the internationally recognized 1-9 scale is used to judge the importance (1, 3, 5, 7, 9), and the judgment matrix group is:

$$\left\{A_l \middle| A_l = [a_{ij}]^l_{n\times m}\right\}(l = 1,2,\cdots,m) \tag{1}$$

Where m is the number of experts and n is the order of the judgment matrix.

3) Weight calculation. Geometric mean approximation method is used to calculate the maximum eigenvalue and eigenvector, and the weight vector is:

$$\overline{w}_i = \sqrt[n]{\prod_{i=1}^{n} a_{ij}} \tag{2}$$

Do normalization on the vector $\overline{w}_i = (\overline{w}_1, \overline{w}_2, \cdots \overline{w}_n)^T$.

$$w_i^1 = \frac{\overline{w}_i}{\sum_{j=1}^{n} \overline{w}_j} j = 1,2,\cdots,n \tag{3}$$

4) Consistency test. Based on the relative weights of the indicators derived in the previous step, a consistency test was conducted, and the judgment was based on RI<0.1.

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(Aw)_i}{nw_i} \tag{4}$$

$$CI = \frac{\lambda_{\max} - n}{n-1}, RI = \frac{CI}{RI} \tag{5}$$

(2) Objective weight calculation

1) Based on the indicator system constructed above, and collect the sample data of electric power material suppliers and standardize them to form the original indicator data set:

$$\{c_{i1}, c_{i2}, \cdots, c_{in}\}, i = 1,2,\cdots,m \tag{6}$$

2) Extracting the common factor, through the covariance matrix, calculating the eigenvalues and eigenvectors, extracting the main factor according to the variance contribution, usually selecting the cumulative variance contribution greater than 80%.

3)Factor rotation and factor analysis, differentiate the factor loading coefficients of the common factors by factor rotation method, enhance the explanatory power of the key factors, and select variance maximizing orthogonal rotation for factor rotation.

4) Determine the indicator weights w_j^2, calculate the score of each factor, generally can use the great likelihood and least squares method to estimate the factor score for each indicator.

$$w_j^2 = \frac{\beta_j}{\sum_{j=1}^{n} \beta_j} \tag{7}$$

(3) Formula for calculating the comprehensive weight vector

Based on the subjective and objective weights calculated above, the normalization method is used to further determine the composite weight of each indicator $W = \{w_1, w_2, \cdots, w_n\}$.

$$w_j = \frac{w_j^1 \times w_j^2}{\sum_{j=1}^{m} w_j^1 \times w_j^2} \tag{8}$$

3.3 Improved fuzzy comprehensive evaluation method algorithm

Improvement of fuzzy comprehensive evaluation method in the consideration of the impact of a variety of factors, the comprehensive consideration of the subjectivity and objectivity of things to calculate the weight of the indicators, and the use of fuzzy mathematical ideas on the comprehensive evaluation of things, the algorithm flow is as follows:

(1) Establish the evaluation factor domain. The target layer thesis is denoted as $U = \{u_1, u_2, \cdots, u_m\}$, where *m* represents the number of criteria under the target layer, and the criterion layer thesis is denoted as $B = \{b_1, b_2, \cdots, b_n\}$, where *n* represents the number of indicator factors under the criterion layer.

(2) Determine the set of alternative rubrics. The comprehensive score is graded, and the internationally recognized nine-level system rating symbol system is adopted, with each level set as [AAA, AA, A, BBB, BB, B, CCC, CC, C].

(3) Establish the fuzzy judgment matrix. Determine the degree of affiliation of the indicators of the factor set under the set of alternative rubrics, known as the affiliation function k (x), and the affiliation degree of positive and negative indicators is calculated as follows:

$$\begin{cases} k(x) = \dfrac{b - b_{j+1}}{b_j - b_{j+1}}, b_{j+1} < b < b_j \\ k(x) = \dfrac{b_{j+1} - b}{b_{j+1} - b_j}, b_j < b < b_{j+1} \end{cases} \tag{9}$$

Where, b_j and b_{j+1} are the two level bounding values adjacent to the actual values of the criterion domain set, respectively, to obtain the affiliation degree of $k(x)$ for the level j rubric set, $1\text{-}k(x)$ for the level j+1 rubric set, and 0 for all the remaining seven levels, and the fuzzy judgment matrix K is formed from the affiliation vector.

(4) Weight calculation. Based on the method described in section 3.2 above, the AHP+FA

algorithm is used to determine the comprehensive weight vector of indicators.

(5) Calculation of fuzzy comprehensive evaluation vector P.

$$P = W \times K \tag{10}$$

(6) Calculate the comprehensive evaluation value S, where D is the standard score of each grade, based on the comprehensive score of the supplier's comprehensive ability into different grades.

$$S = P \times D \tag{11}$$

4 Example analysis

This example utilizes the data of energy meter material suppliers of a State Grid network provincial company to validate the method of this paper. Twelve suppliers who won the bid from January 2017 to March 2017 were selected as the object of analysis, and based on the evaluation index system constructed above, a total of 16 secondary index detail data of 12 power meter suppliers were collected, all of which came from the company's e-commerce platform system and enterprise resource management system. The detailed data of each supplier indicator is shown in the table below.

AHP+FA comprehensive assignment method was used to calculate the comprehensive weight vector of each indicator. Relevant electric power experts were invited to construct the judgment matrix of each indicator in AHP hierarchical analysis method, and the geometric mean method was used to calculate the eigenvectors normalized to get the subjective weights. The selection standard of the main factor in factor analysis method is that the cumulative variance contribution is more than 85%, and it can be found from the factor loading matrix that the factor loading coefficients are less different on each index, then orthogonal rotated variance maximization is used to rotate the factors, which enhances the explanatory power of the key factors, and finally the comprehensive weight of each index is derived based on the formula (9) - (12), which is shown in Table 1.

Table 1 Composite weights of supplier indicator system

Indicator (percentage)	Subjective weighting	Objective weighting	Comprehensive weighting
Total assets	6.26	4.83	4.76
Cooperation	6.72	5.73	6.06
Qualification Score	7.1	7.72	8.62
Return on Net Assets	4.56	5.17	3.71
Asset Debt Ratio	2.27	3.85	1.37
Product qualification rate	14.12	7.31	16.25
Percentage of senior technical personnel	3.38	7.86	4.19
Awards and Patents	5.49	6.7	5.79
Timeliness of contract signing	1.55	3.32	0.81
Supply Completeness	12.23	4.95	9.53

Qualified rate of three orders	4.29	5.64	3.81
Service Qualification Rate	13.82	5.83	12.68
Number of service outlets	1.34	7.45	1.58
Total profit and tax paid rate	6.18	6.9	6.72
Increase in the number of jobs	5.88	8.6	7.96
Charitable Expenditures	4.8	8.15	6.16

The collected data are pre-processed, the nine-level evaluation standard values of each indicator are calculated based on the nine-level scale, and the degree of affiliation of each indicator value to the evaluation standard value of each indicator is calculated. Take the first supplier as an example, the total assets of the nine evaluation criteria for [308 745.23, 272 111.89, 235 478.5,198 845.19, 162 211.84, 125 578.49, 2588 945.15, 52311.79, 15 678.45], the total assets of the supplier is 16,024.56, which is located between the two levels of C and CC. According to the formula 9, the degree of affiliation K1 is 0.99, K2 is 1 minus 0.99, which is equal to 0.01, and the degree of affiliation of other grades is 0. The vector of affiliation of the supplier's total assets is [0, 0, 0, 0, 0, 0,0, 0.01, 0.99]. Similarly, the supplier's matrix of affiliation K for each indicator can be calculated as shown in Table 2.

For the first supplier, based on the calculated weights of each indicator and the affiliation matrix of each indicator value on the nine-level scale, the supplier's fuzzy comprehensive evaluation vector P on the nine-level scale can be calculated by formula 11. We set the nine-level scale score as [100, 90, 80, 70, 60, 50, 40, 30, 20], and finally we can get the supplier's comprehensive score of 72.95. The calculated fuzzy comprehensive evaluation vector P of this supplier is shown in Table 3.

Table 2 Affiliation matrix for the first supplier

AAA	AA	A	BBB	BB	B	CCC	CC	C
0	0	0	0	0	0	0	0.01	0.99
0	0	0	0	1	0	0	0	0
0	0	0	0.44	0.56	0	0	0	0
0	0	0	0	0.33	0.67	0	0	0
0	0	0	0	0.11	0.89	0	0	0
1	0	0	0	0	0	0	0	0
0	0	0.714	0.286	0	0	0	0	0
0	0	0.6	0.4	0	0	0	0	0
1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
0.24	0.76	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
0	0	0.33	0.67	0	0	0	0	0
0	0	0	0	0.43	0.57	0	0	0
0	0	0	0	0	0	0.37	0.63	0
0	0	0	0	0	0	0.6	0.4	0

Table 3 Fuzzy composite evaluation vector for the first supplier

Scale	AAA	AA	A	BBB	BB	B	CCC	CC	C
Value	0.401	0.029	0.07	0.084	0.152	0.075	0.067	0.076	0.048

The final score for this supplier is $S = P \times D = 72.95$。

Similarly, the final scores of all suppliers can be obtained as shown in the table below. In order to represent the evaluation level of each supplier more graphically, the vector [AAA, AA, A, BBB, BB, B, CCC, CC, C] is used to represent the nine levels, as shown in Table 4.

Table 4 Composite scores and grades for each supplier

Rating	1	2	3	4	5	6	7	8	9	10	11	12
Grade	72.95	74.3	31.9	53.86	91.77	46.59	54.76	55.12	47.61	54.68	63.34	72.4
Scale	A	A	CCC	BB	AAA	B	BB	BB	B	BB	BBB	A

As can be seen from Table 4, the overall comprehensive capacity situation of the 12 suppliers is low, of which there are 4 suppliers with ratings of AAA and A, 8 with ratings between BB-BBB, 2 with ratings of B, respectively, supplier 6 and 9, and 1 with a rating of CCC. Further analysis for Supplier 3 for suppliers with lower ratings, as an example, Supplier 3 was found to have a lower rating mainly due to a lower product qualification rate and service qualification rate, which were only 78% and 89% respectively, and a charitable and public welfare expenditure of zero. Therefore, if this supplier wants to win in the next bidding, it needs to start from these three aspects, improve the product qualification rate and service quality, increase the public welfare expenditure, and better fulfill the corporate social responsibility.

Compared with the shortcomings of the traditional fuzzy comprehensive evaluation method, which has a high degree of subjectivity in determining the weights, AHP+FA is used to calculate the weights of the indicators. It takes into account the subjectivity of the comprehensive knowledge of the group of experts and increases the diversity of the system, and also takes into account the actuality and objectivity of the index data, which corrects the shortcomings of the traditional fuzzy comprehensive evaluation method and makes the whole evaluation system more reasonable.

5 Conclusion

Based on the traditional fuzzy comprehensive evaluation method, the article designs a comprehensive evaluation model of electric power supplier based on the improved fuzzy comprehensive evaluation method. Firstly, the evaluation index system is constructed by taking the perspective of corporate social responsibility as the innovation point, and taking into account the enterprise organization factor, product factor, supply factor and after-sale factor comprehensively. Then, in the process of calculating the weight of indicators, the subjectivity of the group and the objectivity of the evaluation system are considered comprehensively, AHP+FA is used to calculate the comprehensive weight of indicators, and fuzzy mathematical method is introduced to calculate the comprehensive level of the supplier, which can provide a certain reference for the bidding and purchasing work of the electric power enterprises, and promote the intensive management of the electric power enterprise materials and the enhancement of the operational efficiency. Finally, the effectiveness and practicality of the model is verified through the analysis of examples. Based on the comprehensive score of suppliers, this paper divides the suppliers into 9 different levels, which can provide a certain reference for the bidding and procurement work of electric power enterprises, and promote the intensive management of electric power enterprise materials and the improvement of operational efficiency. In addition, this paper mainly studies the power supplier evaluation model based on the improved fuzzy comprehensive evaluation method, but the applicability of other industries has to be further studied carefully.

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