A comprehensive evaluation of power suppliers

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Abstract. Aiming at the shortcomings in current power equipment supplier evaluation, this paper is designed for different types of project comprehensive evaluation models. First of all, starting from the type of project and engineering needs, the indicator system was established in four aspects: qualification ability, process control, operation quality, and service quality. Then, the subjective weight and objective weight of each evaluation index were calculated by the fuzzy analytic hierarchy process (AHP) and factor analysis method. The final weight was obtained by a combination weighting method. The supplier category was determined according to the principle of maximum membership, and the final evaluation was completed. Finally, the evaluation model was verified by the distribution transformer supplier, and the results proved the objective rationality of the evaluation model.

1 Introduction

The power grid material supplier is the core link of the power grid material supply chain. The performance evaluation of suppliers can strengthen the ability of material supply guarantee, improve the level of material intensive management, and facilitate the selection of suppliers. It is of practical significance to conduct supplier behavior analysis and supplier comprehensive evaluation [1-2].

At present, the evaluation of suppliers is mainly studied from two aspects: the construction of an evaluation index system and the evaluation method. Literature [3] and [4] constructed evaluation indexes from the aspect of social responsibility, and literature [5-9] used multiple discriminant analysis (MDA), grey clustering trigonometric method, neural network, and support vector machine to evaluate. Due to the particularity of power supply, different types of projects have different material supply objectives. When suppliers need to supply multiple projects at the same time, their bidding standards should be different. The existing methods do not consider this problem. The index design is either too single or too broad and lacks pertinence, resulting in the difference between the evaluation results and the actual situation.

Based on this, this paper first analyzes the demand characteristics of different types of substances for power projects, constructs a comprehensive evaluation index for suppliers,

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and constructs an evaluation model based on the fuzzy analytic hierarchy process (FAHP). The effectiveness and feasibility of the model are verified by example analysis.

2 Construct a comprehensive evaluation index system

The power grid material supply chain is determined by the operation demand of the power grid, which can be divided into engineering demand and non-engineering demand. The engineering demand is determined by the specific power construction project. The non-project category refers to the operation and maintenance of the power grid, which is the demand formed by the operation accident and emergency. As for two types of projects, in addition to quality assurance, the former need to strictly control the supply time, and supplies to strictly match the project schedule; the latter is highly uncertain and requires corresponding speed[10].

Combining the characteristics of these two types of projects, ECP, enterprise resource planning (ERP), manufacture scheduling platform (MDS), power production management system (PMS), and other platforms' various dimensions of data, evaluation indicators[11,12] are established based on the supplier's qualifications and capabilities, process control, product quality, and service support. The evaluation indicators are shown in Table 1.

Table 1. Evaluation system for power grid material supplie.

The primary indicators	The secondary indicators	Indicator description	Indicator type	The data source
Ability of qualification	Qualification of credibility	Assign the value according to the corresponding credit level of the supplier	Semantic phrases	Original data
	engineering performance	Proportion of engineering projects of suppliers in one year	Accurate number	Calculated by formula
	Shipment inspection performance	Proportion of supplier's inspection items in one year	Accurate number	Original data
Process control	Degree of contract fit	Reflect supplier contract signing and performance process	Semantic phrases	Expert scoring
	Sample inspection pass rate	Pass rate of sample inspection	Semantic phrases	Expert scoring
	Progress of production schedule	The supplier completes the schedule of the whole planning process	Accurate number	Original data
	Timeliness of delivery	To reflect the delivery as agreed	Semantic phrases	Expert scoring
Operation quality	Defect rate	The proportion of familial defects in equipment	Accurate number	Calculated by formula
	Failure rate	The percentage of devices that fail	Accurate number	Calculated by formula
	Equipment service life	Normal operating year of the device	Accurate number	Calculated by formula
Service quality	Installation quality	The degree of field support during installation	Semantic phrases	Expert scoring
	Debugging quality	Commissioning and commissioning of equipment	Interval number	Original data
	After-sales quality	The degree of support for equipment repair and maintenance	Semantic phrases	Expert scoring

(1) Ability of qualification: Qualification of credibility, performance of R&D and design engineering projects, and performance of operation and inspection projects are taken as evaluation indicators. Qualification of credibility refers to the credit rating of the supplier. The proportion of annual R&D expenses of R&D design suppliers: engineering project performance, the proportion of engineering projects in one year; performance of inspection projects, the proportion of inspection projects within one year.

(2) Process control: Degree of contract fit, sample inspection pass rate, the progress of the production schedule, and timeliness of delivery. Degree of contract fit and user satisfaction refers to reflect the supplier contract signing and performance process. Based on the progress of the production schedule, the supplier completes the whole planning process with the schedule. The progress of production schedule (qualified) refers to the qualified rate of spot inspection of the arrival of goods and inspects the quality of production. The timeliness of supply reflects the delivery in accordance with the agreement.

(3) Operation quality: Defect rate (the proportion of familial defects in equipment), failure rate (the percentage of devices that fail), equipment service life (normal operating year of the device).

(4) Service quality: Installation quality (the degree of field support during installation), debugging quality (commissioning and commissioning of equipment), and after-sales quality (the degree of support for equipment repair and maintenance)[12].

3 Comprehensive evaluation model

The fuzzy analytic hierarchy process (FAHP) and Factor Analysis (FA) were used to calculate the subjective and objective weights of indicators. Then, combined weights were assigned based on game theory.

3.1 Fuzzy Analytic Hierarchy Process

Fuzzy analytic hierarchy process (FAHP) uses a fuzzy consistency matrix for subjective weighting, which can not only maintain the advantages of traditional AHP, but also ensure the consistency of the judgment matrix.

The fuzzy complementary matrix is constructed, and the n evaluation indexes selected are compared pairwise. Based on the membership degree of the fuzzy relationship between 0.1-0.9, the fuzzy relationship between indexes is quantified to form a fuzzy matrix. Clearly, matrix A is a fuzzy complementary matrix.

$$A=\left[a_{ij}\right]_{n\times n},\quad a_{ij}+a_{ji}=1 \tag{1}$$

The fuzzy complementary matrix is transformed into the fuzzy consistent matrix. The fuzzy complementary matrix A is summed by row, and the fuzzy consistency matrix T is obtained by mathematical transformation using the following formula.

$$T=\left[t_{ij}\right]_{n\times n},\qquad t_{ij}=(t_i-t_j)/2n+0.5 \tag{2}$$

Calculate the weight coefficient. By substituting fuzzy consistent matrix T into AHP, the weight of fuzzy hierarchy ω= (ω1, ω2..., ωn)

$$\omega_i=\frac{2}{n(n-1)}\left(\sum_{j=1}^{n}t_{ij}-1\right)\qquad i=1,2,\cdots,n \tag{3}$$

Modify the index weight coefficient. Formula (4) is used to calculate the similarity degree (Rij) of evaluation weights of each expert index and the deviation degree (Pij) of expert evaluation. In Formula (5), the scores with large deviation degrees are discarded.

$$R = 1 - \sqrt{\frac{\sum_{j=1}^{n}(\omega_{ik} - \omega_{jk})^2}{n}}, \qquad i = 1, 2, \cdots, n \tag{4}$$

$$X_i = \sum_{j=1}^{n} R_{ij}, \quad P_i = \frac{X_{\max} - X_i}{X_{\max}} \times 100\% \tag{5}$$

Consistency test. The consistency check is made according to the weight matrix of the division calculated above, and the judgment basis is CR<0.1.

$$\lambda_{\max} = \sum_{j=1}^{n} \frac{(T\omega)_i}{n\omega_i} \tag{6}$$

$$CI = \frac{\lambda_{\max} - n}{n-1}, \quad CR = \frac{CI}{RI} \tag{7}$$

3.2 Establish the fuzzy relation matrix

Determine the evaluation index, assuming n evaluation objects, C ={c1,c2... cn}, where c1, c2... cn is n evaluation factors participating in the evaluation.

Establish supplier evaluation standard set V, standard set V= {v1, v2... , vm}, where v1, v2... , vm has m evaluation levels. In this paper, suppliers are divided into three levels: A, B, and C (A＞ B＞ C).

Establish the fuzzy membership matrix r, r = (r_{ij})n×m, membership r_{ij} is:

$$r_{ij} = \begin{cases} 1 & x_i \le s_i \\ (s_{j+1} - x_i)/(s_{j+1} - s_i) & s_i < x_i < s_{i+1} \\ 0 & x_i \ge s_{i+1} \end{cases} \tag{8}$$

Factor analysis

Based on the index system constructed above, the collected sample data of power material suppliers are standardized and processed to form the original index data set.

The common factor is extracted, and the eigenvalue and eigenvector are calculated through the covariance matrix. The principal factor is extracted according to the variance contribution degree, and the cumulative variance contribution degree is usually selected to be greater than 90%.

2) The variance-maximizing orthogonal rotation method is used to differentiate the factor loading coefficients of the common factors.

3) The maximum likelihood and least square methods were used to estimate the factor scores and calculate the scores of each index.

$$\omega_j^2 = \frac{\beta_j}{\sum_{j=1}^{n} \beta_j} \tag{9}$$

(4) Game theory combinatorial weighting

The combined weighting method of game theory can fully combine subjective consciousness with the internal distribution of objective data and improve the scientific rationality of weight to a certain extent [12]. Combined weighting method of game theory is used to optimize subjective weight and objective weight.

Table 2. Weight matrix of performance evaluation index of distribution transformer supplier.

Primary indicators			Secondary indicators			Weighted Weightiness
Number	Name	Weightiness	Number	Name	Weightiness	
1	Ability of qualification	0.198	1	Qualification of credibility	0.367	0.072666
			2	Engineering performance	0.313	0.061974
			3	Shipment inspection performance	0.32	0.06336
2	Process control	0.314	4	Degree of contract fit	0.234	0.073476
			5	Sample inspection pass rate	0.282	0.088548
			6	Progress of production schedule	0.228	0.071592
			7	Timeliness of delivery	0.256	0.080384
3	Operation quality	0.227	8	Defect rate	0.324	0.073548
			9	Failure rate	0.361	0.081947
			10	Equipment service life	0.315	0.071505
4	Service quality	0.261	11	Installation quality	0.343	0.089523
			12	Debugging quality	0.336	0.087696
			13	After-sales quality	0.321	0.083781

The analytic hierarchy process and factor analysis method are used to weigh the evaluation index of the supplier, respectively, and the comprehensive weight vector of the evaluation index of the supplier is obtained. ω={ω1,ω2}, where ω1 is the subjective weight vector determined by the analytic hierarchy process, ω2 is the objective weight vector determined by the factor analysis, and the comprehensive weight vector is:

$$\omega = \alpha_1 \omega_1^T + \alpha_2 \omega_2^T \tag{10}$$

According to the idea of the game aggregation model, with the goal of minimizing deviation, the two linear combination coefficients α1 and α2 of the above equation are optimized, and the most satisfactory weight of ω is obtained.

$$f = \min \left\| \omega - \omega_k \right\|_2 , \quad k = 1,2 \tag{11}$$

1) According to the properties of matrix differentiation, the linear system of optimal first-order derivative conditions equivalent to Equation (6) is:

$$\begin{bmatrix} \omega_1\omega_1^T & \omega_1\omega_2^T \\ \omega_2\omega_1^T & \omega_2\omega_2^T \end{bmatrix}\begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix}=\begin{bmatrix} \omega_1\omega_1^T \\ \omega_2\omega_2^T \end{bmatrix} \tag{12}$$

2) The optimal linear combination coefficient is obtained from the above formula. After normalization, the comprehensive weight ω based on the combination weight of game theory is finally obtained as follows:

$$\omega=\alpha_1^*\omega_1^T+\alpha_2^*\omega_2^T \tag{13}$$

Among them, $\begin{cases} \alpha_1^*=\alpha_1/(\alpha_1+\alpha_2) \\ \alpha_2^*=\alpha_2/(\alpha_1+\alpha_2) \end{cases}$.

(5) Comprehensive evaluation model

The comprehensive evaluation model is established, the fuzzy comprehensive evaluation vector is calculated, and the supplier grade is selected by the maximum membership principle max{pj}.

$$P=\omega\cdot R \tag{14}$$

4 The example analysis

In order to verify the feasibility and scientificity of the method proposed in this paper, the distribution transformer is taken as the object, and the data of 7 suppliers in a bidding process is selected for comprehensive analysis. In the example, the data of distribution transformer material suppliers of a State Grid company in a province were used to verify the method in this paper. The suppliers that continuously supplied from 2001 to 2018 were selected as the analysis objects, and an evaluation index system was established.

Table 3. The final layer weight.

Indicator layer	Subjective weight (%)	Objective weight (%)	Comprehensive weights (%)
Qualification of credibility	7.2666	7.942	7.314
Engineering performance	6.1974	5.725	6.164
Shipment inspection performance	6.336	6.643	6.357
Degree of contract fit	7.3476	9.716	7.513
Sample inspection pass rate	8.8548	9.372	8.891
Progress of production schedule	7.1592	8.913	7.282
Timeliness of delivery	8.0384	6.153	7.906
Defect rate	7.3548	5.237	7.207
Failure rate	8.1947	9.587	8.292
Equipment service life	7.1505	9.319	7.302
Installation quality	8.9523	5.372	8.702
Debugging quality	8.7696	6.528	8.613
After-sales quality	8.3781	9.495	8.456

There are different data sources and types of indicators, such as qualification of credibility, degree of contract fit, sample inspection pass rate, timeliness of delivery, installation quality, after-sales quality, and other indicators are semantic indicators; engineering performance, shipment inspection performance, the progress of production schedule, defect rate, failure rate, and equipment service life are accurate figures. After deliberation by experts and decision-makers, the value range of each index is determined, and the value of each index is normalized.

The weight matrix of the performance evaluation index of distribution transformer suppliers is shown in Table 2. The final weight is shown in Table 3.

The final evaluation result can be achieved, which is consistent with the actual situation. Taking the supplier with the code T-04 as an example, the membership degrees of A, B, and C are 0.243, 0.693, and 0.064, respectively, and the supplier is evaluated as B level. The evaluation results of suppliers are shown in Table 4.

Table 4. Statistics of supplier scores.

Supplier	A	B	C	Level
T-01	0.643	0.295	0.062	A
T-02	0.763	0.180	0.057	A
T-03	0.045	0.264	0.691	C
T-04	0.243	0.693	0.064	B
T-05	0.032	0.361	0.607	C
T-06	0.692	0.305	0.003	A
T-07	0.231	0.761	0.008	B

The results of the proposed method and the traditional fuzzy analytic hierarchy process are compared, and the results are shown in Table 5. The evaluation results of T-03, T-04, T-06, and T-07 are different. Evaluated in a traditional method, T-03 and T-07 are A, T-04 is C, and T-06 is B. While evaluation in this method, T-03 is C, T-07 is B, T-04 is B, and T-06 is A. This indicates that the traditional method will omit the internal rules between the data, resulting in the difference between the evaluation results and the actual situation.

Table 5. Comparison of evaluation methods.

Supplier	Evaluation result	
	The traditional AHP	The Present Paper
T-01	A	A
T-02	B	A
T-03	A	C
T-04	C	B
T-05	C	C
T-06	B	A
T-07	A	B

5 Conclusion

This paper first established the indicator system in four aspects: qualification ability, process control, operation quality, and service quality, for different engineering needs of different projects. Then, the subjective weight and objective weight of the evaluation index were calculated by AHP and factor analysis, respectively. Then the combined weighting model of game theory is used to calculate the comprehensive weight of the index. In the end, the suppliers are graded by comprehensive evaluation. Examples verify the effectiveness and practicability of the model.

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