

Research on Supplier Comprehensive Evaluation Model Based on TOPSIS - Gray Relational Analysis

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ABSTRACT

With the increase in the price of raw materials and the cost of transportation and storage, people pay more and more attention to the ordering problem of production enterprises. Therefore, how to choose a better supplier becomes the focus of the moment. This problem is essentially an evaluation decision-making problem. This paper first analyzes the supply characteristics of suppliers, then defines four indicators, namely, supply strength, supply stability, supply surplus rate and shortage rate, determines the integrated subjective and objective weights by using the analytic hierarchy process and principal component analysis method, and on this basis, establishes a comprehensive evaluation system coupled with TOPSIS-Gray relational analysis to evaluate the importance of 402 suppliers, and finally decides the most important supplier by combining the proportion of raw materials ordered by enterprises and taking the average supply volume as the limit.

Keywords: *supply chain analysis, analytic hierarchy process, principal component analysis, TOPSIS, grey relational analysis*

1. INTRODUCTION

Under the pressure of the global market, improving the production process must optimize the flow from all aspects and gain advantages through effective supply management. [1] The neighboring enterprises show the relationship between supply and demand, linking the neighboring enterprises in turn to form a supply chain. [2] At present, the key to the survival of an enterprise is whether the problems of changing customer orders, uncontrollable inventory and high supply cost can be solved. Reasonable and effective evaluation of suppliers is a vital link to ensure the stable development of enterprises [3].

2. WEIGHT OF SUBJECTIVE AND OBJECTIVE INDICATORS BASED ON AHP-PCA METHOD

2.1. Selection of Evaluation Indicators

Firstly, according to the cooperation flexibility criterion and credit level criterion, the supply characteristics are quantified as four indicators: supply surplus rate, supply shortage rate, supply volume, and supply interannual stability.[4]

Cooperation flexibility criteria:

- Stability of suppliers' supply resources

The more resources the supplier can provide, the enterprise can dynamically adjust the number of goods ordered according to the production situation and changes in market demand and other emergencies, reduce transportation and storage costs, and ensure the maximum productivity benefit.

$$x_{i1} = \frac{\sum_{j=1}^N \text{supply}_{ij}}{N} \tag{1}$$

- Interannual stability of supplier supply

The supplier's annual supply capacity is small, that is, the supply resource is stable, indicating that the supplier - the cooperative relationship between manufacturers is more stable, and the interrupt risk is low, and it can maintain long-term stable supply and demand relationship. If the annual supply volume is large, that is, the amount of supply resources fluctuates is large, and the relationship between suppliers – manufacturers is weaker.

$$x_{i2} = \sqrt{\frac{\sum_{i=1}^5 (\text{year} - \text{year}_{iq})^2}{5}} \tag{2}$$

- Supplier supply surplus rate

Suppose the supplier provides the goods per week greater than or equal to corporate order. In that case, you can guarantee the company's capacity to ensure the enterprise's production efficiency. Let the ratio of the supplier's supply to be greater than the order, that is, the supply surplus rate of the i-th supplier in the j-th week, which is r_{ij}^1 , then:

$$r_{ij}^1 = \frac{\text{supply}_{ij}}{\text{order}_{ij}} - 1 \quad (3)$$

Therefore, i-th supply surplus rate x_{i3} is:

$$x_{i3} = \frac{\sum_{j=1}^N r_{ij}^1}{N} \quad (4)$$

- Lack of supply from suppliers

If the goods supplied by the supplier per week are less than or equal to the order quantity of the enterprise, the enterprise may have the potential that the demand is greater than the supply, resulting in a decrease in the economic benefits of the enterprise. If the supplier's supply volume is less than the proportion of the order volume, the i-th supplier's supply miss rate in j-th week is r_{ij}^2 , then:

$$r_{ij}^2 = \frac{\text{supply}_{ij}}{\text{order}_{ij}} - 1 \quad (5)$$

Therefore, the missing supply rate of the i-th supplier is x_{i4} :

$$x_{i4} = \frac{\sum_{j=1}^N r_{ij}^2}{N} \quad (6)$$

Table 1. Indicator Judgment Matrix

	Source stability	Annual stability of supply	Lack of supply rate	Supply surplus rate
Source stability	1	6	4	3
Annual stability of supply	1/6	1	1/3	1/4
Lack of supply rate	1/4	3	1	0.5
Supply surplus rate	1/3	4	2	1

Firstly, the consistency of the matrix is checked, and the CR value is $0.0297 < 0.100$, so the consistency of the matrix is acceptable. Secondly, the maximum eigenvalues and eigenvectors of the matrix are solved, and the weights of the four indexes $\varphi_{x1}, \varphi_{x2}, \varphi_{x3}, \varphi_{x4}$ are 0.5497, 0.2386, 0.1467 and 0.0650, respectively.

Step2: Principal Component Analysis to Calculate Objective Weights

2.2. Determination of Indicator Weight

Before establishing a comprehensive evaluation model, it is necessary to calculate and determine the weights of the above four supply characteristic indicators. Analytic Hierarchy Process (AHP) is a systematic and hierarchical analysis method that combines qualitative and quantitative methods. The characteristic of this method is that on the basis of in-depth research on the nature, influencing factors and internal relationships of complex decision-making problems, it uses less quantitative information to mathematicalize the thinking process of decision-making, so as to provide multi-objective, multi-criteria or Complex decision-making problems without structural characteristics provide easy decision-making methods. [5] Using AHP can assign weights to the above four indicators. Since the AHP determines that the weight is too subjective, the introduction of the main component analysis method is analyzed to analyze data differentiation, and more comprehensive AHP-PCA maintenance-intensive weight is obtained. [6] To sum up, set the weights of analytic hierarchy process as $\varphi_{x1}, \varphi_{x2}, \varphi_{x3}, \varphi_{x4}$, the weights of principal component analysis method as $\varphi_{y1}, \varphi_{y2}, \varphi_{y3}, \varphi_{y4}$, and the integration weights as $\varphi_1, \varphi_2, \varphi_3, \varphi_4$, and solve the weights as follows:

Step1: Analytic Hierarchy Process to Calculate Subjective Weight

Refer to the relevant literature of supplier supply characteristics and analyze the relationship between indicators, and list the judgment matrix as follows:

Taking the four supply characteristic index matrices as the characteristic vectors, the principal component analysis method is adopted to calculate the weights. It is assumed that the supply characteristic index sets of suppliers are: $X = \{x_1, x_2, x_3, x_4\}$, the corresponding weight sets are $W = \{\varphi_{y1}, \varphi_{y2}, \varphi_{y3}, \varphi_{y4}\}$, and the specific formula for solving the weights is as follows:

$$\varphi_{x_j} = \frac{\sum_{i=1}^n \lambda_i \varepsilon_{ij}}{\sum_{i=1}^n \lambda_i} \quad (7)$$

The covariance eigenvalues and eigenvectors of each supply index are obtained through calculation, and the objective index weight values $\varphi_{y1}, \varphi_{y2}, \varphi_{y3}, \varphi_{y4}$ calculated by principal component analysis method are 0.4709, 0.2981, 0.1708 and 0.0626 respectively according to the

Table 2. AHP- PCA indicator set weights

	Source stability	Supply surplus rate	Lack of supply rate	Annual stability of supply
AHP weights	0.5497	0.2386	0.1467	0.0650
PCA weights	0.4709	0.2981	0.1708	0.0602
Aggregate weight	0.5103	0.2684	0.1587	0.0626

As can be seen from the table, the characteristics of supply resource volume dominate the selection of suppliers.

3. TOPSIS - GREY RELATIONAL ANALYSIS COUPLING DEGREE COMPREHENSIVE EVALUATION SYSTEM

TOPSIS is one of the commonly used multi-objective decision analysis methods. Its essence is to judge the development level of the system by measuring the Euclidean distance between the actual state and the ideal state of the system.[7] However, using distance as a scale can only reflect the positional relationship of the data curve nail clippers, but cannot reflect the dynamic changes of the data sequence. [8] Grey relational analysis is a measure of the degree of closeness between system factors, which can well reflect the changing situation of the system. [9] In this paper, the combination of TOPSIS thought and grey relational analysis theory can more credibly evaluate the importance of suppliers. [10]

Based on the comprehensive indicators and their weights, the TOPSIS- Grey relational analysis coupling degree comprehensive evaluation system is established as follows:

• TOPSIS method determines the importance of suppliers

Step 1: Establish a normalized matrix from the established evaluation index system and standardize the data, namely

$$Z_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^n X_{ij}^2}} (i = 1, \dots, 402; j = 1, 2, 3, 4) \quad (8)$$

formula.

Step 3: AHP- PCA Indicator Set Weights

The aggregate weights obtained by adding and averaging the subjective weights and the objective weights are shown in the following table:

Step2: Get the optimal vector based on the normalized matrix Z as follows:

$$Z_j^+ = \max_{1 \leq i \leq 402} |Z_{ij}| \quad (9)$$

The worst vectors are as follows:

$$Z_j^- = \min_{1 \leq i \leq 402} |Z_{ij}| \quad (10)$$

Step3: Calculate the Euclidean distance between the index value of each supplier of the selected four comprehensive evaluation indexes and the optimal vector:

$$D^+ = \sqrt{\sum_{j=1}^4 (Z_{ij} - Z_j^+)^2} \quad (11)$$

Euclidean distance from the worst vector:

$$D^- = \sqrt{\sum_{j=1}^4 (Z_{ij} - Z_j^-)^2} \quad (12)$$

Step4: Calculate the relative proximity between each supplier and the optimal vector, i.e., the comprehensive score (significance) of each supplier:

$$W_{1i} = \frac{D_i^-}{D_i^+ + D_i^-} \quad (13)$$

• Determining the Importance of Suppliers by Grey Relational Analysis

Step1: Standardized processing of data, using the matrix after standardized processing by TOPSIS method.

$$Z_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^n X_{ij}^2}} (i = 1, \dots, 402; j = 1, 2, 3, 4) \quad (14)$$

Step2: Determine Reference Sequence and Comparative Sequence

$$X_0 = (X_0(1), X_0(2), X_0(3), X_0(4)), X_0(j) = \max_{1 \leq i \leq 402} |Z_{ij}| \quad (15)$$

$$X_k = (Z_{k1}, Z_{k2}, Z_{k3}, Z_{k4}), k = 1, \dots, 402 \quad (16)$$

Step3: Calculate the correlation between the comparison sequence and the reference sequence

$$y(X_0(k), X_i(k)) = \frac{a + \rho b}{|X_0(k) - X_i(k)| + \rho b} \quad (17)$$

$$a = \min_k |X_0(k) - X_i(k)|, b = \max_k |X_0(k) - X_i(k)| \quad (18)$$

Step4: Calculate Correlation

$$Y(X_0, X_i) = \frac{1}{n} \sum_{k=1}^n y(X_0(k), X_i(k)) \quad (19)$$

• Calculate the Average Composite Score

Table 3 Proportion of Three Raw Materials to Total Ordered Quantity

Types of raw materials	A	B	C
Proportion weight	0.3516	0.3299	0.3185

Therefore, out of the 50 suppliers selected, 18 provide raw material A, 16 provide raw material B and 16 provide raw material C. Considering the needs of the production capacity of enterprises in actual production, large and medium-sized suppliers are selected as alternatives. Therefore, the average supply of three raw materials A, B, and C by suppliers is not less than 100, 50, and 100, respectively, as the limit, we can choose a more reliable supplier according to the ranking from high to low.

4. CONCLUSION

Firstly, the supply characteristics of suppliers are analyzed. As the weight calculation of AHP is too subjective, the principal component analysis method is considered to obtain the subjective and objective integrated weight. Secondly, from the perspective of enterprise production of raw materials. The unit production capacity consumes the same cost of the three raw materials A, B and C. Therefore, it is necessary to determine the preference of the enterprise in purchasing the three raw materials and consider the ratio of the order quantity of the three raw materials to the total order quantity.

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Record the supplier's comprehensive score obtained by the TOPSIS method as $Score_{1i}$, and the integrated score of each supplier obtained by gray-related analysis method as $Score_{2i}$, and the two will be equal to the average. The average integrated score of the merchant is:

$$Score_i = \frac{(Score_{1i} + Score_{2i})}{2} \quad (20)$$

• The Solution of the Comprehensive Evaluation System

When using the comprehensive evaluation system to judge 402 suppliers, considering that each of the three raw materials A, B and C needs its own supplier, the selected 50 suppliers should be chosen from the suppliers corresponding to the three raw materials A, B and C according to a certain proportion.

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