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# A Study on the Supplier Evaluation and Selection System Based on PCA and TOPSIS

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***Abstract:***With the continuous development of market economy, the competition among suppliers for enterprises has become more and more intense. It is understood that most enterprises in China have not yet formed a scientific and comprehensive supplier evaluation and selection system. In order to help enterprises make objective and specific evaluation of suppliers, this paper establishes a supplier evaluation and selection system model based on principal component analysis (PCA) and TOPSIS method. First of all, from the supplier supply strength and supply stability of the two aspects, refine the five indicators to measure the characteristics of supplier, and then use the principal component analysis to refine and simplify the index data, and calculate the score of each supplier using TOPSIS method. The most important suppliers can be obtained by comparing the scores. Finally, according to the actual capacity needs of enterprises,to calculate the number of suppliers required.

***Keywords:*** Supplier Evaluation and Selection System;Principal Component Analysis; TOPSIS

## 1. Introduction

With the rapid development of the economy, market competition has become more and more intense. For production-oriented enterprises, there are more suppliers to choose from when purchasing, so a comprehensive evaluation of suppliers is the basis and prerequisite to select suppliers properly. However, most domestic enterprises mostly rely on the subjective judgment of managers when choosing suppliers, and have not yet formed a comprehensive, objective and comprehensive evaluation system, so this paper launched a series of studies on the construction of supplier evaluation and selection system.

Based on the data related to Question C of the 2021 China Undergraduate Mathematical Contest in Modeling, this paper extracts indicators to measure the supply characteristics of each supplier and quantifies them for the demand situation of a production-oriented enterprise, establishes a supplier evaluation system model, selects the most important suppliers among them, and screens the required suppliers according to the capacity demand of the enterprise.

## 2. Current Status of Somestic Research

At present, domestic research methods for supplier evaluation and selection mainly include Analytic Hierarchy Process (AHP), Fuzzy Evaluation method, principal component analysis method and TOPSIS method[1-2]. Cao Shuo[3] constructed an analytic hierarchy process structure model based on the AHP method, judged the consistency test of the matrix group, quickly provided the priority order of the comprehensive evaluation of suppliers, and provided a relatively accurate basis for managers, but the data statistics will be larger when there are too many indicators, and the weights are difficult to determine, the qualitative components are too much . In order to avoid the influence of subjective factors in AHP, Zhang Zhen[4] et al proposed a supplier evaluation method combining AHP and fuzzy comprehensive evaluation, but it is not easy to distinguish the affiliation degrees when using fuzzy comprehensive evaluation method, which may affect the evaluation .

This paper adopts the combination of principal component analysis method and TOPSIS method to study the supplier selection problem in supply chain management, reduces the dimension of decision-making data through principal component analysis, and uses TOPSIS method to assist in completing supplier decision-making, effectively improving the efficiency of decision-making and reliability of results.

# 3. Establishment of Supplier Evaluation and Selection System Model

Accordingto the data, we can know the relevant information of the company's 402 suppliers (ID, the type of raw materials provided by each supplier, the company's 240-week order volume from each supplier in each week, and the supplier's weekly supply for the company,etc). Through the analysis of the data, it is found that the fluctuations of the supply data of different suppliers are quite different, and the supply scale of different suppliers is different. In order to select the most important and suitable suppliers, it is necessary to Extract the evaluation indicators to construct an evaluation system.

## 3.1 Selection and quantification of supplier supply characteristic indicators

First, the indicators to measure the supply characteristics are extracted from the company's order quantity and the supplier's supply volume, and then the supply characteristics are quantified according to the indicators. Since there are two main aspects to ensure the importance of enterprise production, one is the supply strength of suppliers, and the other is the stability of suppliers' supply.

**1) Supply Capacity**

The supplier's supply capacity can be measured by the supplier's total supply volume within 5 years, the average volume of each supply and the average annual growth rate of the supply volume.

① Total supply refers to the total amount of goods provided by a supplier in 5 years. The higher the value, the larger the scale of production and operation of the supplier, which can be used as an effective indicator to measure the scale of supplier's production , and its specific calculation formula is:

$$TS_i = \sum_{j=1}^{240} ts_{ij} \quad (1)$$

where $TS_i$ is the total supply of the $i^{th}$ supplier, and the $ts_{ij}$ is the supply of the $i^{th}$ supplier for the $j^{th}$ week.

② The average supply quantity per time refers to the average value of each supply quantity of a certain supplier. The higher the value is, the larger the supplier's supply quantity is. The specific calculation formula is:

$$AS_i = TS_i / n_i \quad (2)$$

where $AS_i$ is the average quantity of each supply from the $i^{th}$ supplier, and the $n_i$ is the number of supplies from the $i^{th}$ supplier.

③ The average annual growth rate of supply refers to the average annual growth rate of a supplier from the first year to the fifth year. The overall volume is on the rise, which can be used as an effective indicator to measure the transaction volume of enterprises. The specific calculation formula is as follows:

$$D_i = \frac{1}{4}\sum_{k=1}^{4} \frac{ys_{i,(k+1)} - ys_{i,k}}{ys_{i,k}} \quad (3)$$

where $D_i$ is the average annual growth rate of the supply of the $i^{th}$ supplier, and the $ys_{i,k}$ is the total supply of the $i^{th}$ supplier in the $k^{th}$ year.

**2) Supply Stability**

Supply stability refers to the stability of the relationship between the production-oriented enterprise and the supplier. First, it can be measured by the fluctuation between the demand of the enterprise and the supply of the supplier. The smaller the degree of fluctuation, the more stable the relationship between supply and demand is. The second is to measure the supplier's ability to supply in a timely manner according to the ratio of the number of times the supplier's supply actually meets the demand of the enterprise to the total number of supplies. The higher the ratio, the stronger the supply stability. Therefore, the coefficient of variation of the difference between the supplier's supply and the order quantity and the proportion of the satisfied order quantity are selected as indicators to measure the supply stability.

① The variance of the difference between the supply quantity and the order quantity refers to the dispersion of the difference between the supply quantity and the order quantity of a certain supplier. Here, the variance can be used to measure

the stability of the supplier's supply, which is convenient for comparison between suppliers. The smaller the variance, the more consistent the supplier's weekly supply is with the company's order volume, and the more stable the supply and demand relationship is. The variance is also called unit risk. The specific calculation method is:

$$S_i^2 = \frac{1}{240}\left[(d_{i1} - \overline{d_i})^2 + (d_{i2} - \overline{d_i})^2 + \cdots (d_{i240} - \overline{d_i})^2\right] \quad (4)$$

Among them, $S_i^2$ is the variance of the difference between the $i^{th}$ supplier's supply and the order quantity, $d_{ij}(j = 1,2\cdots 240)$ is the difference between the $i^{th}$ supplier's supply and the order quantity in the $j^{th}$ week, and $\overline{d_i}$ is the arithmetic mean of the 240-week difference of the $i^{th}$ supplier.

② The ratio of meeting the order quantity refers to the ratio of the number of times a supplier's supply meets the order quantity to the total order quantity. The higher the ratio, the more stable the supply-demand relationship. Its specific calculation method is

$$H_i = m_i / n_i \quad (5)$$

where $H_i$ is the proportion of the $i^{th}$ supplier meeting the order quantity, and $m_i$ is the number of times that the $i^{th}$ supplier's supply meets the order quantity.

In summary, in terms of the construction and selection of indicators, five possible impact indicators are summarized.

## 3.2 The establishment of Model

The evaluation of supplier's supply characteristics is a process of multiple causes and one effect. There are many indicators affecting the results, and there is a complex relationship between the indicators. Therefore, the principal component analysis method combined with the TOPSIS method is used to evaluate the supply characteristics. On the one hand, It can make full use of the advantages of principal component analysis for dimensionality reduction analysis and weight determination of a large number of variables, and on the other hand, TOPSIS can be used for effective quantitative analysis[5]. The specific process is as follows:

1) Positive processing of negative indicators (include the variance of the difference between the supply quantity and the order quantity and the proportion of unsatisfied order quantity);

2) Standardize the data after forwarding;

3) Calculate the correlation coefficient matrix, eigenvalues and eigenvectors;

4) Calculate the contribution rate of eigenvalues: $c_i = \lambda_i / m$, where $\lambda_i$ represents the eigenvalue corresponding to the $i^{th}$ principal component, and $m$ is the number of original index variables. According to the cumulative contribution rate, $p(p \leq 5)$ principal components are selected as the final indexes to construct the evaluation system, and then the contribution rate $c_i$ is used as the weight.

5) Calculate and normalize the score $S_i$ using TOPSIS:

## 3.3 Analysis of examples

According to the basic steps of the principal component analysis method, using MATLAB software, the principal component analysis of the five evaluation indicators of the two levels can be performed, and the eigenvalues, contribution rates and cumulative contribution rates of the correlation coefficient matrix can be obtained as shown in Table 2.

Table 1 Eigenvalues, contribution rate and cumulative contribution rate of correlation coefficient matrix

| Serial Number | Eigenvalues | Contribution rate | Cumulative Contribution rate |
|---|---|---|---|
| 1 | 2.3122 | 46.2433 | 46.2433 |
| 2 | 1.0308 | 20.6161 | 66.8594 |
| 3 | 0.9522 | 19.0450 | 85.9044 |
| 4 | 0.6620 | 13.2408 | 99.1452 |
| 5 | 0.0427 | 0.8548 | 100 |

# 4. Establishment of Supplier Screening Model

Based on the above supplier evaluation and decision-making system, it is further considered that if the weekly production capacity demand of the enterprise is $W$ cubic meters, at least how many suppliers need to be selected to meet the normal production demand, so two expected goals must be achieved: one is to make the the number of suppliers as small as possible; the other is to make the selected supplier have a high evaluation score and high reliability, so the following target model is constructed:

$$min\frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} y_i \cdot S_i} \quad (6)$$

Where $y_i$ is a logical vari*a*ble, which takes the value of "0" or "1". When it is "1", it means that the $i^{th}$ supplier supplies this week; $S_i$ is the supplier score index in the supplier evaluation and selection model, which symbolizes the importance of the supplier.

If the enterprise requires three kinds of raw materials: $A,B\ and\ C$, each cubic meter of production capacity needs to consume $\alpha$ cubic meters of A raw materials, or $\beta$ cubic meters of B raw materials, or $\gamma$ cubic meters of C raw materials, each supplier will provide only one of these raw materials, if each supplier expects the weekly supply volume is $R_i$, the average supply volume of each supplier $AS_i$ and the proportion of each supplier meeting the order volume $H_i$ are known in the foregoing, where $i = 1,2,3, \ldots, 403$. The supplier's expected weekly supply is affected by the supplier's average supply each time and the proportion of each supplier's fulfilled order quantity. The satisfying relationship is as follows:

$$R_i = AS_i \cdot (1 - H_i), \quad i = 1,2,3\ldots,403 \quad (7)$$

Therefore, according to formula (7), the expected supply quantity of each supplier can be calculated.

At the same time, it is considered that there will be a certain loss in the transfer process from the supplier to the enterprise. In order to ensure that the receiving volume of the enterprise can still meet the normal production needs, the loss rate of the forwarder during the transfer is set as $\sigma_i$ ,thus the expected capacity needs to satisfy the following constraints:

$$\sum_{i=1}^{n} \frac{y_i R_{i,t}(1-\sigma_{i,t})}{p_i} \geq W, \quad t = 1,2,3\ldots,24 \quad (8)$$

$$p_i = \alpha, i \in A$$

$$p_i = \beta, i \in B$$

$$p_i = \gamma, i \in C$$

$$y_i \in \{0,1\}$$

Where, $p_i$ is the raw m*ater*ial consume*d* to product unit cubic meter of production capacity, $R_{i,t}$ is the supply quantity of the $i^{th}$ supplier in the $t^{th}$ week, and $\sigma_{i,t}$ is the transshipment loss rate of the $i^{th}$ supplier in the $t^{th}$ week.

Equations (6) and (8) are the supplier screening model, which is a supplement and extension to the evaluation decision model. Using this model, enterprises can screen out the fewest and most suitable suppliers that can meet the production needs of the enterprise. .

# 5. Conclusion

The supplier selection problem is a hot issue in supply chain management. Based on the principal component analysis method in statistical knowledge, this paper extracts, quantifies and simplifies the supply characteristics of suppliers, and then combines the multi-objective decision-making TOPSIS method to analyze it. After further analysis, the evaluation score of each supplier is finally obtained, which makes supplier decision-making more efficient, and also effectively improves the reliability of decision-making. In addition, this paper also builds a supplier screening model, which can screen out the least number and the most suitable suppliers according to the production capacity demand of the enterprise and the supply situation of the suppliers, which has certain practical significance.

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