

Supplier Selection Problems for Production Enterprises

Yucheng Jin, Xuewen Shen*

College of Media Engineering, Communication University of Zhejiang, Hangzhou, China

*Corresponding Author, E-mail: cuzmath@126.com

Abstract

Identifying the right suppliers is critical to keeping the supply chain functioning properly. The implementation of an assessment system will substantially simplify the selection of enterprises. Following the initial screening, the supply characteristics are evaluated from three perspectives: risk, volatility, and total supply. Based on this, we construct a grey correlation model analysis to confirm objective weight by correlation degree value, set up the TOPSIS model to determine the comprehensive evaluation score in a systematic manner, select the 50 most important suppliers to ensure production, and finally run model tests using the K-means algorithm.

Keywords

Grey Correlation Analysis; TOPSIS Model; K-means Algorithm; Multi-objective Optimization.

1. Research Background

Supply chain refers to a whole functional network chain structure containing suppliers, manufacturers, distributors and users. It revolves around the core enterprises, starting from the accessories, manufacturing intermediate products and final products, and finally delivering them to consumers by the sales network. A production enterprise often cooperate with various raw materials suppliers to ensure the normal operation of the supply chain. Considering the number of suppliers is larger when its delivery capacity is also variant, selecting suppliers erroneously will result in interruption of production plans, increase of inventory costs, delay in the delivery of raw materials, postponement in the conveyance of finished products and other adverse consequences. For production enterprises, choosing suppliers is the key to their survival and development. Therefore, production enterprises should evaluate the synthetic competitiveness of each supplier and select optimal number of suppliers to meet their production needs.

Aiming at this problem, we take the weekly supply data of 402 raw material suppliers of a production enterprise (production raw materials have A, B and C) within 240 weeks as an example, and study the 50 suppliers that are most in line with the production plan of the production enterprise.

2. Model Assumptions

- 1) The enterprise acquires all the raw materials provided by the supplier.
- 2) Only consider the core factors in the problem: the production plan of the enterprise and the supplier's supply capacity; Other factors not involved in the problem are not considered.
- 3) When preprocessing attachment data, the influence of some other factors is negligible.
- 4) The selected indicators: the total supply, supply risk and supply volatility can represent the overall situation of the research object.
- 5) The supplier's initial data in the attachment is treated as zero.

3. Symbol Description

Table 1. Meaning and Explanation of Symbols

symbol	illustrate	unit
M	Total supply	m^3
X_a	The supply of the supplier to the enterprise on a weekly basis	m^3
r	Supply risks	
Y_a	The number of weekly orders placed by the company against the supplier	m^3
w	Volatility in supply	
σ_a	The standard deviation of the supplier's supply to the enterprise in the new supply sequence	
$\bar{x}_a$	The average of the supplier's supply to the company in the new supply sequence	m^3
Z	The number of target vendors	piece
c_i	Select the matrix	
m	Number of weeks	
x_{ij}	Weekly supply per supplier	m^3
l	Loss parameters	

4. Model Building

This paper analyzes how to select the optimal 50 suppliers based on the company's weekly production capacity. Firstly, we perform data mining processing on Annex 1[4], extract the relevant indicators and use reasonable quantification; Secondly, we construct a variable weight function to determine the evaluation weights of the relevant indicators; Finally, according to the quantitative index score of the supplier, we conduct a comprehensive ranking.

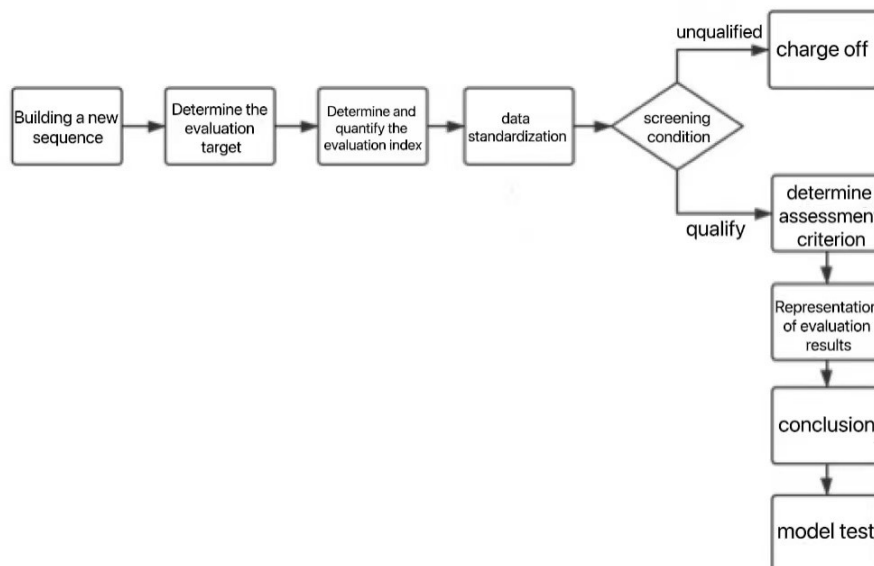


Figure 1. Supplier selection flowchart

4.1. Data Preprocessing

Annex 1[4] shows the order and supply data of 402 raw material suppliers for the past 5 years, including each supplier's weekly order from the production enterprise and its own weekly supply. Since enterprises must formulate a 24-week raw material ordering and transshipment plan in advance, we process the time series of the nearly five years in the annex, taking 1-24

weeks as the basis and one week as the unit time span, constructing a new incremental time series for supply and order quantity, and making a difference to construct a new sequence.

4.2. Determination of Supplier Evaluation Index

We define the indicators that measure the supplier's ability to ensure the production of the enterprise.

4.2.1. Total Supply

Definition1: The total supply of suppliers to production enterprises in the past 5 years (240 weeks) is M :

$$M = \sum_{a=1}^{240} x_a \quad (1)$$

X_a represents the weekly supply of suppliers to the enterprise in the past five years.

Without considering other factors, the total supply of suppliers to enterprises represents the quantity of goods exported by suppliers to enterprises in recent times, which can reflect the supplier's supply capacity to a certain extent, taken as one of the indicators to evaluate the importance of suppliers to ensure the production of enterprises.

4.2.2. Supply Risk

Definition2: The average of the ratio of the difference series to the sequence of orders is r

$$r = \frac{Y_a - X_a}{X_a} \quad (2)$$

In the formula, X_a represents the weekly supply of suppliers to the enterprise in the past five years, Y_a represents the weekly order volume of the enterprise to the supplier in the past five years.

It is determined that the enterprise is always all the raw materials that the supplier can actually provide, so we take the difference between the order quantity and the supply quantity in the incremental time series as the numerator, and the order quantity in the incremental time series as the denominator, then strike the average after the operations, and the credibility of the enterprise measured by the proportion of the supplier's satisfaction with the order of the enterprise, taken as one of the indicators to evaluate the importance of the supplier to ensure the production of the enterprise.

4.2.3. Supply Volatility

Definition3: The ratio of the standard deviation of the sequence of supply to the mean of the sequence of supply is w .

$$w = \frac{\sigma_a}{\bar{x}_a} \quad (3)$$

In the formula, σ_a represents the standard deviation of the supplier's supply to the enterprise in the supply sequence, $\bar{x}_a$ represents the average value of the supplier's supply to the enterprise in the supply sequence.

The standard deviation of the sequence of supply represents the degree of dispersion of supply in the past five years in the weekly time span, which can reflect the fluctuation of the supplier's

supply in the time cycle to a certain extent, used to measure the stability of the company's supply, taken as one of the indicators to evaluate the importance of the supplier's production to ensure the enterprise.

4.3. Comprehensive Evaluation Model based on Grey Association Analysis and TOPSIS Method

Based on the above supplier evaluation indicators, the objective weight of the indicator is determined by grey correlation degree, and quantitative analysis is carried out by TOOPSIS method. Each supplier is weighted and scored, and the supplier supply evaluation system is constructed.

First, we consider the quantitative indicators in the system. As the weekly production capacity of the enterprise is 28,200 cubic meters, here we exclude the enterprises with a total supply of less than 100 cubic meters in the past five years. Meanwhile, we consider the confidence risk of the enterprise. For the enterprise with a high supply risk index, it is more likely to have accidents such as the supply less than the order, so we do not consider the enterprises with a supply risk of more than 0.9.

Finally, we preliminarily selected 169 suppliers for evaluation and analysis.

4.3.1. Data Standardization

Due to the different nature of each evaluation index in the supplier evaluation system, we should standardize the original data to ensure the reliability of the results. In this system, since the coexistence of positive and negative indicators, we use dispersion standardization according to equation (4) to ensure that the new sequence is dimensionless and positive.

$$b_i = \frac{a_i - a_{\min}}{a_{\max} - a_{\min}} \quad (4)$$

4.3.2. Grey Association Analysis

The grey relational analysis is a method to measure the degree of correlation between factors according to the degree of similarity or difference of their development trend.

The specific steps are as follows:

Step1. Determine the reference and comparison sequences.

Reference series: $A_j = (A_j(1), A_j(2), A_j(3)), j = 0$.

Comparison sequence:

$$A_i = (A_i(1), A_i(2), A_i(3)), i = 1, 2, 3 (\text{Number of sub factors})$$

Step2. Calculate the correlation coefficient.

Define the association function as follows:

$$\xi_{ji}(k) = \frac{\min_i \min_k |A_j(k) - A_i(k)| + \rho \max_i \max_k |A_j(k) - A_i(k)|}{|A_j(k) - A_i(k)| + \rho \max_i \max_k |A_j(k) - A_i(k)|} \quad (5)$$

Step3. Calculate the degree of correlation.

Define the degree of association:

$$r_{ji} = \frac{\sum_{k=1}^n \xi_{ji}(K)}{n} \quad (6)$$

In the formula, n is 169, representing 169 sample points (data from 169 suppliers).

Step4. Judge the relevance.

Combined with practical background, there is a negative effect called negative correlation, otherwise positive correlation; $|r_{ji}|$ greater than 0.7 is called a strong correlation, and less than 0.3 is called a weak correlation.

4.3.3. Topsis Algorithm

Topsis algorithm is a common multi-objective decision analysis method with limited schemes. The principle is to calculate the comprehensive evaluation value of each scheme, and then sort the scheme according to the size of the comprehensive evaluation value. The steps are as follows:

Step1. Using the vector programming method to obtain a standardized decision matrix, this problem has three properties to decide the problem, so we set the decision matrix of the three indicator decision problems as $A = (a_{ij})_{m \times n}$, the normalized decision matrix, which is $B = (b_{ij})_{m \times n}$.

$$b_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^m a_{ij}^2}}, i = 1 \dots m, j = 1 \dots n \quad (7)$$

Step2. Constitutes a weighted gauge matrix $C = (c_{ij})_{m \times n}$ and given a weight vector for three properties $\omega = [\omega_1, \omega_2, \omega_3]^T$, $c_{ij} = \omega_j \cdot b_{ij}$, $i = 1 \dots m, j = 1 \dots n$.

Step3. Determine the positive and negative ideal solutions and determine the distance from each scheme to them. Let the value of the j th attribute of the positive ideal solution be c_j^* , the value of the j th attribute of the negative ideal solution be c_j^0 , and the distance from the alternative d_i to the positive ideal solution is:

$$s_i^* = \sqrt{\sum_{j=1}^n (c_{ij} - c_j^*)^2}, i = 1 \dots m, j = 1 \dots n \quad (8)$$

The alternative distance to the negative ideal solution is:

$$s_i^0 = \sqrt{\sum_{j=1}^n (c_{ij} - c_j^0)^2}, i = 1 \dots m \quad (9)$$

Step4. A comprehensive evaluation index for each programme is obtained through calculation

$$f_i^* = \frac{s_i^0}{s_i^0 + s_i^*}, i = 1 \dots m \quad (10)$$

Step5. According to the order of the comprehensive evaluation index from largest to smallest, the optimal 50 suppliers were determined.

4.4. Model Tests

The evaluation ranking obtained in this question is determined based on the comprehensive evaluation score. Therefore, the accuracy of the comprehensive evaluation score of our suppliers is the key to the accuracy of the results of this question, and the results of the supplier comprehensive evaluation score are tested and analyzed below.

We selected the top 10 and the bottom 10 suppliers calculated by the model to analyze them in K-means; Since K-means is an unsupervised clustering algorithm based on Euclidean distances, the dimensions with large means and variances will have a decisive impact on the clustering of the data, so we standardize the data before clustering and use Tableau to derive the algorithm results in the last section.

5. Results and Discussion

5.1. Supplier Evaluation Index

The total supply volume, supply risk (Figure 2) and supply volatility (Figure 3) of the 402 suppliers calculated by the supplier evaluation system can intuitively understand the capability of each supplier in all aspects. However, since the quantitative analysis and evaluation of supplier supply characteristics is a process of multiple causes and one effect, it may have a certain degree of subjectivity in the comprehensive evaluation, so we propose to use the grey correlation degree to determine the objective weight of the indicator, and combine the TOPSIS method to conduct quantitative analysis, weight the score of each supplier, and build a supplier supply evaluation system.

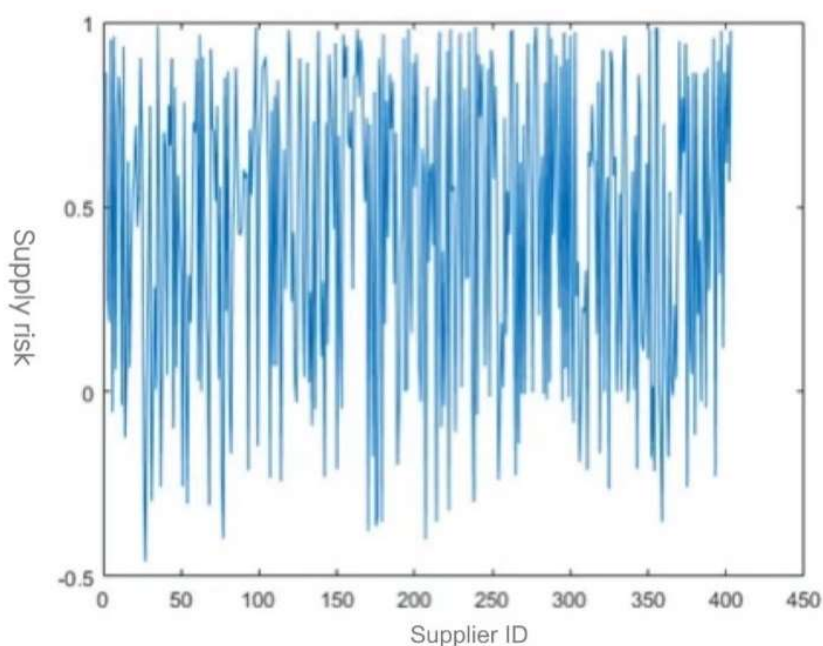


Figure 2. Supply risk indicator chart of 402 suppliers

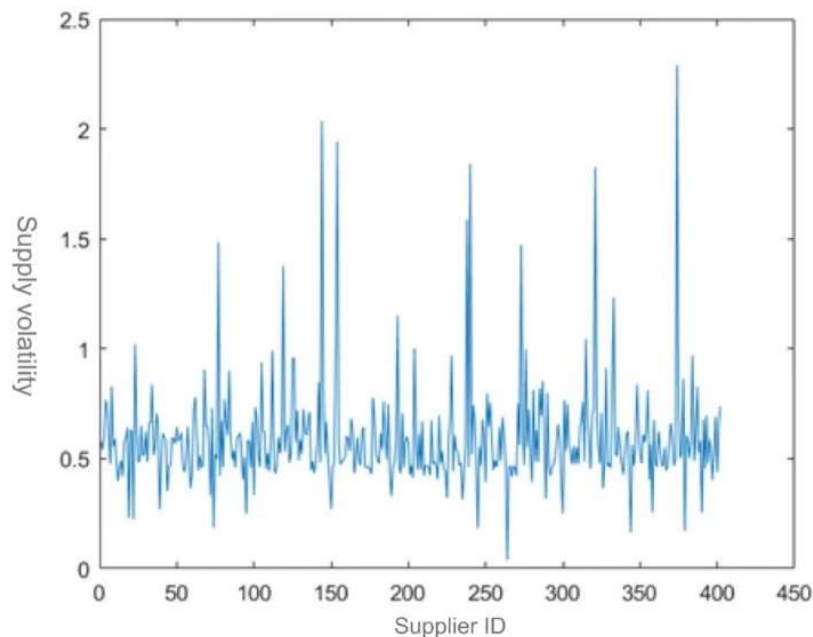


Figure 3. Supply volatility indicator chart of 402 suppliers

5.2. Comprehensive Evaluation Model based on Grey Association Analysis and TOPSIS Method

First of all, through the method of grey correlation analysis, with the help of MATLAB to calculate the correlation matrix (Table 2), it can be seen from the table that the relation degree of the total supply amount, the supply risk degree and the supply volatility are 0.3596, 0.5440, 0.7506. It shows that the three factors affecting the choice of suppliers are sorted as: stability > reliability > availability. Then, calculate the comprehensive evaluation index by Topsis algorithm, and the optimal 50 suppliers are determined according to the order of the comprehensive evaluation index from large to small. The calculation results are shown in (Table 3). It can be seen that the comprehensive score of several suppliers such as S229 and S361 is higher.

Table 2. Correlation matrix composed of total supply, supply risk and supply volatility based on grey correlation analysis

Subfactors	Total supply	Degree of supply risk	Volatility in supply
Relevance	0.3596	0.5440	0.7506

Table 3. Vendors based on the composite evaluation index

Vendor ID	S229	S361	S140	S108	S151
score	0.890087	0.866363	0.774591	0.686848	0.568856
Vendor ID	S340	S282	S275	S329	S139
score	0.536621	0.533724	0.51117	0.506888	0.489898

Note: Due to the large size of the entire table, only parts are shown here.

5.3. Model Tests

In the model inspection, we made a scatter chart of the comprehensive score of the 169 suppliers participating in the evaluation and the three indicators, as shown in Figure 4:

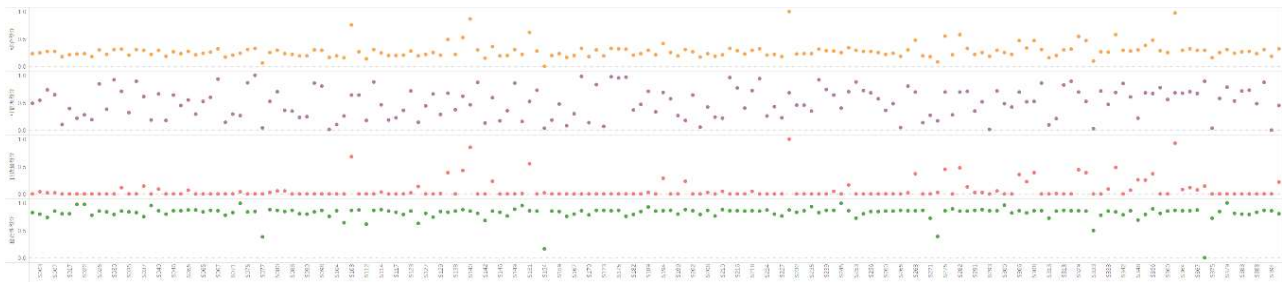


Figure 4. Suppliers score scatter plot

The figure can be found intuitionistic that it is basically in line with the positive correlation, so the model has a certain rationality.

However, the above model test is only an intuitive image comparison after all, with a certain subjective color and error, so we conduct further objective calculation test of the model. Therefore, we select the top 10 and the bottom 10 from the 50 suppliers calculated by the model to analyze K-means clustering, and the results are shown in Figure 5. We can find that the results of clustering are completely consistent with the model conclusions, so the model can be considered reasonable and the test passes.

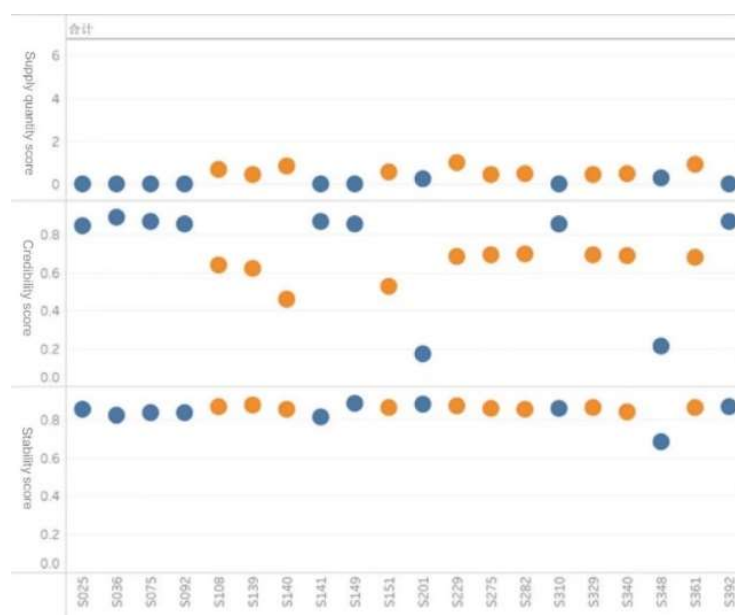


Figure 5. Cluster Validation Diagram of Top 10 and Last 10 Suppliers

6. Conclusion

Firstly, the total supply, supply risk and supply volatility of 402 suppliers are calculated through the supplier evaluation system to investigate the strength of each supplier. Secondly, we construct a grey correlation model analysis to confirm objective weight by correlation degree value and set up the TOPSIS model to determine the comprehensive evaluation score in a systematic manner. Then, the model is tested by the K-means average algorithm. Finally, it is confirmed that the enterprise can cooperate with several raw material suppliers such as S229, S361, S140 and S108 to ensure sufficient raw material supply and minimize risk.

References

- [1] Qiyuan Jiang, Jinxing Xie, Jun Ye: Mathematical Models (Fourth Edition)(Higher Education Press,China 2011).

- [2] ZHUO Jinwu,LI Biwen,WEI Yongsheng,QIN Jian: Application of MATLAB in Mathematical Modeling(Beijing University of Aeronautics and Astronautics Press, China 2014).
- [3] Zhu Daoyuan et al.:Selected Mathematical Modeling Cases(Beijing: Science Press, China 2003).
- [4] Information on: <http://www.mcm.edu.cn>.
- [5] Zhao Lindu: Supply chain and logistics management theory and practice(Beijing : Mechanical Industry Press,China 2003).