

# Research on Raw Material Ordering and Transportation for Enterprises Based on Goal Planning

Xin Liu

Zhejiang Sci-Tech University, Hangzhou, 310018, China.

2019330301053@mails.zstu.edu.cn

**Abstract.** The ordering and transportation of raw materials have an important impact on the operations of enterprises. In this paper, the importance of suppliers is measured by three indicators, namely, suppliers' supply efficiency, supply capability and reputation. Based on the three evaluation indicators, the evaluation system of supplier importance is developed, and the TOPSIS evaluation method is used to rank the suppliers. After pre-processing the given data, we set up a multi-objective optimization model with the objectives of minimum number of suppliers, minimum expected total cost of raw materials and minimum amount of loss in transit, and figured out the minimum loss of raw materials of 4526.066 cubic meters. The correctness and validity of the model were demonstrated by comparing the loss of raw materials in the last five years.

**Keywords:** TOPSIS Evaluation Method; Data Pre-processing; Multi-objective Optimization Model.

## 1. Introduction

The overall raw materials required by a manufacturing enterprise can be divided into three types: A, B and C. In combination with the production method of the enterprise, there are three options for the raw materials to be consumed per cubic meter of product, i.e., consume only raw material A, consume only raw material B, or consume only raw material C. The enterprise needs to plan 24 weeks of raw material ordering and forwarding plan in advance before proceeding to produce the product. The enterprise should determine the suppliers that can provide raw materials in combination with its own production capacity demand, the weekly order quantity of raw materials required, the raw materials that can provide transportation, and the number of raw materials that can be supplied by the forwarders and suppliers each week.

Due to the special nature of the production of raw materials, the actual supply of suppliers will generally deviate from the order quantity of enterprises. In order to meet the normal production needs of enterprises, enterprises generally buy all the raw materials provided by suppliers to ensure that as far as possible the inventory of raw materials is more than two weeks of production needs.

In the process of transporting raw materials by forwarders, there will be a certain loss of raw materials due to some factors. Therefore, the accepted quantity shipped to the enterprise warehouse will be smaller than the supply quantity from suppliers. At the same time, the raw materials supplied by one supplier each week are basically transported by one forwarder, and each forwarder has a weekly transport limit of 6,000 cubic meters.

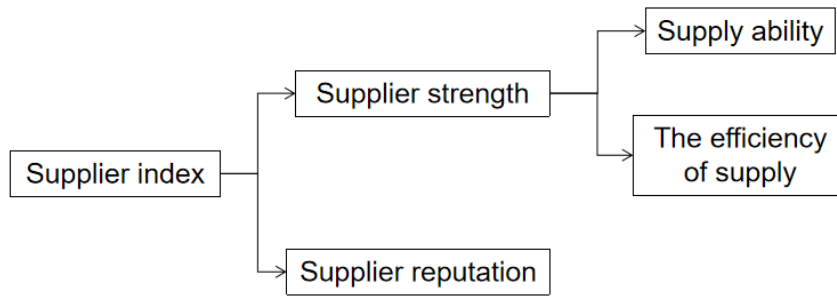
Since the ordering costs of the three raw materials are different, it is particularly important for companies to choose the right type of raw material for production. In practice, the order unit price of A and B raw materials is 1.2 times and 1.1 times than that of C raw materials respectively, but the unit price of transportation and storage is the same for all three.

## 2. Evaluation of Suppliers

### 2.1 Selection of Supplier Indicators

According to the selection principles of raw material suppliers in the supply chain and the related evaluation model, the supplier's supply characteristics are quantitatively analyzed to build a supplier risk assessment model that reasonably guarantees production, and a primary indicator model is established in terms of the supplier's supply strength and credibility. Then, the secondary index model

is established through the analysis of supplier strength, and the index hierarchy model is shown as follows.



**Figure 1.** Schematic Diagram of the Indicator Hierarchy Model

## 2.2 Quantitative Analysis of Supplier Indicators

### 2.2.1 Supply Efficiency

Supply efficiency is an important indicator to reflect whether the supplier can meet the normal production needs of the enterprise. In the case of not considering the loss, only when the supplier's supply is greater than or equal to the enterprise's order quantity, can it meet the enterprise's production needs.

In order to determine whether the firm in week  $j$  orders from the supplier  $i$ , we introduce the 0-1 variable  $k_{ij}$ , i.e.

$$k_{ij} = \begin{cases} 1, & \text{if the enterprise orders from supplier } i \text{ in week } j \\ 0, & \text{other} \end{cases} \quad (1)$$

A value of 1 for  $k_{ij}$  indicates that the enterprise orders from the supplier  $i$  for the  $j$ th week, and a value of 0 for  $k_{ij}$  indicates that the enterprise does not order from the supplier  $i$  for the  $j$ th week.

The specific formula for supply efficiency is:

$$P_i = \frac{\sum_{j=1}^{240} x_{ij}}{\sum_{j=1}^{240} y_{ij}} \quad (2)$$

where  $P_i$  is the supply efficiency,  $x_{ij}$  is the supply quantity from the supplier  $i$  for the  $j$ th week, and  $y_{ij}$  is the order quantity from the supplier in week  $j$ .

### 2.2.2 Supply Capability

Supply capacity can reflect the comprehensive production capacity of suppliers. Suppliers with strong supply capability are often able to meet the demand for enterprise production. In this paper, we select the average value of suppliers to provide enterprise supply within 5 years as a measure of suppliers' supply capability. The specific formula of supply capability is as follows:

$$A_i = \frac{1}{n} \sum_{j=1}^{240} x_{ij} \quad (3)$$

where  $A_i$  is the capability of the supplier  $i$ , and  $n$  is the total number of weeks ordered and trans-shipped over a 5-year period.

### 2.2.3 Credibility

The credibility of the supplier is reflected in the frequency of raw materials ordered by the enterprise. The higher the credibility of the supplier is, the more times the enterprise orders. The specific calculation formula is as follows:

$$C_i = \frac{1}{n} \sum_{j=1}^{240} k_{ij} \quad (4)$$

where,  $C_i$  is the reputation of the enterprise to the supplier  $i$ .

## 2.3 Modelling of Supplier Importance Evaluation System

### 2.3.1 Background of TOPSIS Model

TOPSIS method is a common comprehensive evaluation method, which can make full use of data information to construct an idealized target based on sample data. For instance, our case is to construct a supplier with the best evaluation index in all aspects, and then calculate the relative proximity between the actual supplier and the ideal supplier, as a basis for evaluating the merits, i.e., the closer the relative proximity is, the higher the importance of the supplier will be.

Since all three categories are very large indicators, no forwarding is required.

### 2.3.2 TOPSIS Algorithm Steps

#### (1) Normalization of the Converted Matrix

We define the converted matrix that consists of 402 suppliers to be evaluated and 3 evaluation indicators as,  $X = (a_{im})_{402 \times 3}$ , i.e.,

$$X = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ \vdots & \vdots & \vdots \\ a_{402 \times 1} & a_{402 \times 2} & a_{402 \times 3} \end{bmatrix} \quad (5)$$

To eliminate the effect of dimensionality, the converted matrix  $X$  is normalized. The normalized matrix is noted as  $Z$ , where each element of the matrix is as follows:

$$z_{im} = \frac{a_{im}}{\sqrt{\sum_{i=1}^{402} a_{im}^2}} \quad (6)$$

#### Calculate the Optimal Value and the Worst Value of Each Index

Find the maximum and minimum values of the supplier importance indicators in each column, denoted as  $z_m^+$ ,  $z_m^-$  ( $m = 1, 2, 3$ ), and compose them into separate vectors as follows.

$$\text{Vector of the Optimal Value: } Z^+ = (z_1^+, z_2^+, z_3^+) \quad (7)$$

$$\text{Vector of the Worst Value: } Z^- = (z_1^-, z_2^-, z_3^-) \quad (8)$$

where the optimal value vector represents the most desirable supplier and the worst value vector represents the least desirable supplier.

#### (3) Calculate the Distance Between Each Evaluation Unit and the Optimal Value & the Worst Value

We define the distance between the supplier  $i$  and the most desirable supplier as  $D_i^+$ , and the distance between the supplier  $i$  and the least desirable supplier be  $D_i^-$ , i.e.

$$D_i^+ = \sqrt{\sum_{m=1}^3 (Z_m^+ - z_{im})^2} \tag{9}$$

$$D_i^- = \sqrt{\sum_{m=1}^3 (Z_m^- - z_{im})^2} \tag{10}$$

(4) Calculate the Evaluation Score

We define the evaluation score of suppliers  $i$  as  $S_i (i = 1, 2, 3, \dots, 402)$ , i.e.

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{11}$$

Obviously, the value range of  $S_i$  is  $[0,1]$ , and when  $S_i$  is closer to 1, it means that the closer the supplier is to the most desirable target, the higher the importance of this supplier is. The flow chart of TOPSIS algorithm is shown as follows.

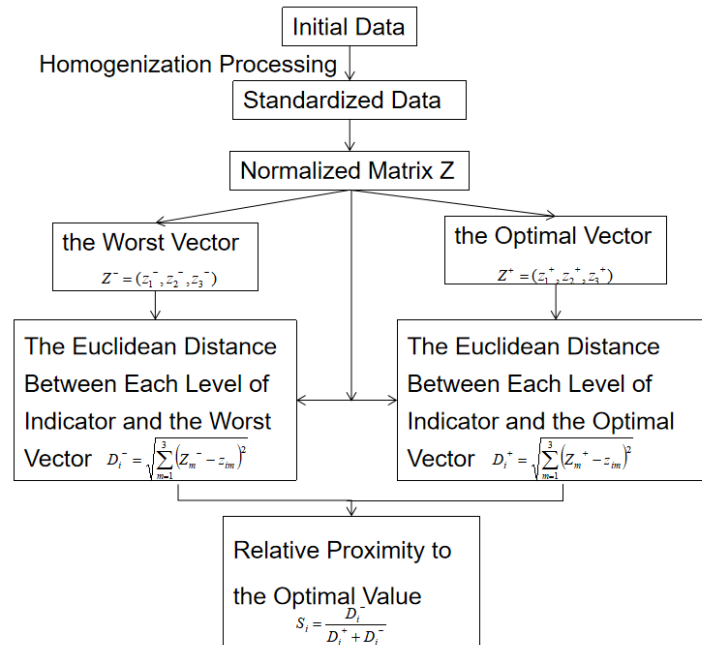


Figure 2. Flow Chart of the TOPSIS Algorithm

### 2.4 Result Analysis

Table 1. Top 10 Supplier Scores and the Corresponding Numbers

Supplier	Type of Raw Material	Score	Number
229	A	0.015612	1
201	A	0.014250	4
395	A	0.009482	6
282	A	0.008419	9
275	A	0.008024	11
329	A	0.007951	12
348	A	0.006192	19
307	A	0.006071	21
352	A	0.00577	22
143	A	0.005599	24

We used the data calculated from Question C of the 2021 Contemporary Undergraduate Mathematical Contest in Modeling to filter the top 10 suppliers as shown in Table 1.

### 3. Enterprise Raw Material Ordering and Transportation Optimization Model

#### 3.1 Optimal Raw Material Ordering and Transportation Scheme Modeling

##### (1) Decision Variables

To determine whether the supplier  $i$  can provide raw materials to the enterprise, a decision variable based on the top 50 suppliers  $B_i (i = 1, 2, 3, \dots, 50)$  is introduced, i.e.

$$B_i = \begin{cases} 1, & \text{if the enterprise chooses the } i\text{th supplier to serve} \\ 0, & \text{other} \end{cases} \quad (12)$$

In order to determine whether or not forwarder  $c$  is forwarding raw materials from supplier  $i$  in week  $j$ , the decision variable  $A_{cij}$  is introduced, i.e.

$$A_{cij} = \begin{cases} 1, & \text{in week } i, \text{ forwarder } c \text{ transfers raw materials from supplier } i \\ 0, & \text{other} \end{cases} \quad (13)$$

##### (2) Objective Function

Taking into account the actual needs of the enterprise, the following three objective functions were selected:

Minimum number of suppliers

$$\min \sum_{i=1}^{50} B_i \quad (14)$$

Minimum expected total cost:

$$\min 1.2 \sum_{i=1}^{16} y_{ij} + 1.1 \sum_{i=17}^{31} y_{ij} + \sum_{i=32}^{50} y_{ij} \quad (15)$$

Minimum amount of loss in transit:

$$\min \sum_{c=1}^8 \sum_{j=1}^{24} t_{cj} P_{cj} \quad (16)$$

Constraints

Constraint of enterprise capacity:

$$\frac{\sum_{i=1}^{16} y_{ij} n_{ij}}{0.6} + \frac{\sum_{i=17}^{31} y_{ij} n_{ij}}{0.66} + \frac{\sum_{i=32}^{50} y_{ij} n_{ij}}{0.72} \geq \frac{2.82}{1-1.3883\%} \quad (17)$$

Constraints on transshipment capacity:

$$\sum_{i=1}^{20} A_{cij} b_{cij} \leq 6000 \quad (18)$$

Constraint of enterprise order quantity:

$$\begin{cases} 0 \leq y_{ij} \leq m_i + 3\sigma_i \\ y_{ij} \in Z \end{cases} \quad (19)$$

Constraint of transshipment volume:

$$\sum_{c=1}^8 b_{cij} = y_{ij} n_{ij} \quad (20)$$

Establishment of Multi-objective Planning Model

$$\begin{cases}
 \min \sum_{i=1}^{50} B_i \\
 \min 1.2 \sum_{i=1}^{16} y_{ij} + 1.1 \sum_{i=17}^{31} y_{ij} + \sum_{i=32}^{50} y_{ij} \\
 \min \sum_{c=1}^8 \sum_{j=1}^{24} t_{cj} p_{cj}
 \end{cases}$$

$$s.t. \begin{cases}
 \frac{\sum_{i=1}^{16} y_{ij} n_{ij} B_i}{0.6} + \frac{\sum_{i=17}^{31} y_{ij} n_{ij} B_i}{0.66} + \frac{\sum_{i=32}^{50} y_{ij} n_{ij} B_i}{0.72} \geq \frac{2.82}{1 - 1.3883\%} \\
 \sum_{i=1}^{50} A_{cij} b_{cij} \leq 6000, c = 1, 2, \dots, 8 \\
 0 \leq y_{ij} \leq m_i + 3\sigma_i \\
 \sum_{c=1}^8 b_{cij} = y_{ij} n_{ij} \\
 y_{ij} \in Z
 \end{cases} \tag{21}$$

where  $t_{cj}$  is the loss rate of raw materials transported by forwarder  $c$  at week  $j$ ,  $p_{cj}$  is the transshipment volume of forwarder  $c$  at week  $j$ ,  $b_{cij}$  is the transshipment volume of forwarder  $c$  to supplier  $i$  at week  $j$ ,  $m_i$  is the average supply volume of the first 80% of suppliers over a 5- year period, and  $\sigma_i$  is the standard deviation of supplier  $i$ 's supply volume.

**3.2 Optimal Raw Material Ordering and Transportation Model Solution**

For the solution of multi-objective planning model, it is usually converted into a single-objective planning model by assigning certain weights to each objective. For this model, we assign each objective a weight ratio of least supplier: least expected total cost: least transit loss = 4:3:3, and solve the model by using Lingo software to obtain the most economical raw material ordering scheme and the transit scheme with the least amount of loss. In addition, the minimum total cost of the enterprise is 80,124.6 units, and the minimum loss of raw materials transported by the forwarder is 4,526.066 m3. By calculation, we can get the average loss of 6,090.977 cubic meters in the next 5 years, and the comparison shows that the transshipment solution is reasonable and reliable.

**4. Conclusion**

Based on the data information such as the order quantity of raw materials, the supply quantity of suppliers and the loss rate of transshipment, the mathematical model is used to solve the problem of ordering and transporting raw materials for enterprises.

For the evaluation of supplier's capability, comprehensive consideration of supplier strength and reputation are needed for quantitative analysis. We used the supplier's supply capacity and supply efficiency to determine the strength of the supplier, and applied the past five years' frequency of enterprises to order raw materials to determine the credibility of the supplier. We combined the above data by using TOPSIS method to establish the importance of supplier evaluation model, and give priority to the supplier enterprises with higher scores.

The multi-objective planning model is established by taking the selection of suppliers and their corresponding transshipment volume of forwarders as the decision variables. The small number of suppliers, the low expected total cost, and the low loss of transshipment are considered as the objective function. The constraints of enterprise capacity, forwarder's transshipment capacity, enterprise order quantity, and transshipment volume are considered comprehensively to build a multi-

objective planning model. It is concluded that the minimum total cost of the enterprise is 80,124.6 units, and the minimum loss of raw materials transported by the forwarder is 4,526.066 cubic meters. Through the calculation, we have known that the average loss of raw materials transported by the forwarder in the past 5 years is 6,090.977 cubic meters, and the comparison shows that the forwarding solution is reasonable and reliable.

For the multi-objective planning model, the stochastic nature of the actual supplier supply and transit loss rate are taken into account, making the model more realistic and the results more accurate.

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