# Research on Raw Material Ordering and Transportation Strategy Based on Integer Programming

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**Abstract.** This paper studies the raw material ordering and transportation strategy based on the principle of integer programming. Based on the production data of a certain enterprise, the original attachment data is firstly analyzed, 6 indicators are selected and the weight coefficient of each indicator is determined by the TOPSIS entropy weight method. Then, a 0-1 integer programming model for solving the minimum number of suppliers is established, and the most economical ordering scheme model is established with the least comprehensive cost as the objective function. Finally, taking the minimum transshipment loss as the goal and the transporter's carrying capacity as the constraint condition, the transshipment plan is solved by the greedy algorithm. After analyzing the ordering plan and the transshipment plan, the ordering plan can meet the weekly production demand, and the average weekly inventory is 59540 cubic meters, the mean square error is 222.67 cubic meters; the average loss of the transshipment scheme is 8.33%, and the ratio of suppliers with two or more transshipments to the total suppliers is 3.85%.

**Keywords:** raw material ordering and shipping, TOPSIS entropy weight method, 0-1 integer programming, greedy algorithm.

## 1. Introduction

The supply of raw materials is of great significance to ensure the normal production of production enterprises. As the starting point of the supply chain, the choice of suppliers is directly related to the efficiency and market competitiveness of downstream manufacturers[1]. This paper studies the ordering plan and transportation plan of raw materials for production enterprises, and selects the production data of a certain enterprise as the research object. The specific information is:

The raw materials used by the production enterprises of the building and decorative panels are mainly wood fibers and other plant fiber materials, which can be divided into three types: A, B, and C. The company arranges production every year for 48 weeks. It needs to formulate a 24-week raw material order and transfer plan in advance, determine a third-party logistics company, and entrust it to transfer the supplier's weekly supply of raw materials to the company's warehouse.

The weekly production capacity of the enterprise is 28,200 cubic meters, and each cubic meter of product needs to consume 0.6 cubic meters of Class A raw materials, or 0.66 cubic meters of Class B raw materials, or 0.72 cubic meters of Class C raw materials. In the actual transfer process, there will be a certain loss of raw materials.

The purchase cost of raw materials directly affects the production efficiency of the enterprise. In practice, the purchase unit price of Class A and Class B raw materials is 20% and 10% higher than that of Class C raw materials, respectively. The unit cost of transportation and storage of the three types of raw materials is the same[2].

According to the above information, firstly, quantitatively analyze the supply characteristics of 402 suppliers, establish a mathematical model that reflects the importance of guaranteeing the production of enterprises, and determine the 50 most important suppliers on this basis, and list the results in the paper.

# 2. Model construction and solution

## 2.1 Evaluation Model Based on TOPSIS Entropy Weight Method

Quantitative analysis of the supply characteristics of 402 suppliers shows that from the existing research literature, when people study the evaluation indicators of suppliers, they do not seek a universally applicable evaluation index system. Each researcher generally uses a variety of methods such as survey method and literature method to determine the supplier evaluation index system according to the specific industry and specific enterprise, showing a certain research way of thinking of "concrete analysis of specific problems". We consider the overall situation and quantify the three indicators of supplier supply, satisfaction and cooperation, including annual average supply, supply stability, average satisfaction, satisfaction volatility, cooperation closeness and cooperation stability 6 sub-indicators[3].

Next, the obtained data are coupled together to establish a mathematical model that reflects the importance of ensuring the production of the enterprise.

The entropy weight method is an objective weighting method. In the specific use process, according to the dispersion degree of the data of each index, the entropy weight of each index is calculated by information entropy, and then the entropy weight is modified according to each index to a certain extent. A more objective indicator weight is obtained[4]. In order to make the evaluation process more standardized, objective and unified, and to avoid the influence of subjective evaluation on the real situation, the entropy weight method is used to determine the weight coefficient of each index. In the TOPSIS method, a limited number of evaluation objects are ranked according to their proximity to the idealized goal, and the relative merits of the existing objects can be evaluated, and the 50 most important suppliers can be finally determined[5].

The calculation steps of the TOPSIS entropy weight method are as follows:

(1) step1 data forward

Firstly, it is necessary to analyze the positive and negative directionality of these indicators, that is, to analyze the influence of the value of this indicator on road traffic[6]. Positiveness is defined as the larger the index value, the better, and negativeness as the smaller the index value, the better. As shown in Table 1.

Table 1 Positive and negative tropism of each indicator

| index | Positive and negative phase |
|---|---|
| Average annual supply | + |
| Supply stability | - |
| average satisfaction | + |
| Satisfied with volatility | - |
| closeness of cooperation | + |
| Cooperation stability | + |

To normalize negative data, use the formula:

$$\bar{x} = \max(X) - x \tag{1}$$

Among them, $\bar{x}$ represents the transformed result, and $x$ represents the original data.

(2) step2 data normalization

After forwarding, there is still the problem that all values have their own dimensions. In order to eliminate the influence of data dimension, it is necessary to standardize the data[7]. The way to normalize the data is as follows:

Suppose k metrics $X_1, X_2, ..., X_K$ are given, where $X_i = \{x_1, x_2, ..., x_n\}$. Assuming that the normalized value of each indicator data is $Y_1, Y_2, ..., Y_k$, then $Y_i = \frac{x_i}{\sqrt{\sum_{i=1}^{n} x_i^2}}$.

Since the two indicators of the supply situation, the annual average supply quantity and the supply stability range are too large, in order to reduce the absolute value of the data and facilitate the calculation, the logarithm of the data is processed, so as to achieve the purpose of convenient calculation[8].

(3) step3 Find the information entropy of each indicator

According to the definition of information entropy in information theory, the information entropy of a set of data:

$$E_j = -\ln(n)^{-1} \sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{2}$$

where $p_{ij} = \frac{Y_{ij}}{\sqrt{\sum_{i=1}^{n} Y_{ij}}}$, if $p_{ij}$, defines $\lim_{p_{ij} \to 0} p_{ij} \ln p_{ij} = 0$.

(4) step4 Determine the weight of each indicator

According to the calculation formula of information entropy, the information entropy of each index is calculated as $E_1, E_2, ..., E_k$. Calculate the weight of each indicator through information entropy: $w_i = \frac{1 - E_i}{k - \sum E_i} (i = 1, 2, ..., k)$.

(5) step5 scoring construction

The distance of the optimal solution is recorded as $D_i^+$, $D_i^+ = \sqrt{\sum_{j=1}^{n} (x_{ij} - \max x_i)^2}$; the distance of the worst solution is recorded as $D_i^-$, $D_i^- = \sqrt{\sum_{j=1}^{n} (x_{ij} - \min x_i)^2}$. The final evaluation index S is: $S = \frac{D^-}{D^+ + D^-}$.

The closer S is to 1, the better.

The model is solved below. Using python programming, according to the obtained data, the weight of each index is obtained by using the entropy weight method, see Table 2.

Table 2 Weight of each indicator Weight of each indicator

| | Average annual supply | Supply stability | average satisfaction | Satisfied with volatility | closeness of cooperatio | Cooperation stability |
|---|---|---|---|---|---|---|
| Weights | 0.3436 | 0.0280 | 0.0859 | 0.0158 | 0.3143 | 0.2124 |

Then, according to the TOPSIS method, the individuals are evaluated and ranked, and the top 50 suppliers are obtained, which are the 50 most important suppliers. The 50 suppliers were classified and summarized according to raw materials A, B, and C, and the results are shown in Table 3.

Table 3 50 Most Important Suppliers

| type | A | B | C |
|---|---|---|---|
| enterprise | S299, S275, S329, S282, S352, S143, S114, S266, S007, S123, S291, S150, S348, S307 | S340, S108, S131, S330, S308, S139, S031, S140, S040, S364, S367, S346, S055, S338, S098 | S361, S268, S306, S194, S356, S151, S247, S374, S284, S365, S294, S080, S218, S244, S086, S314, S074, S003, S076, S129, S037 |

## 2.2 Ordering and Shipping Scenario Model

### 2.2.1 Supplier selection

Assuming that the supply is cyclical, we examine the cyclical relationship of suppliers' supply to the enterprise. The relationship between the monthly supply and time of some suppliers is shown in Figure 1.

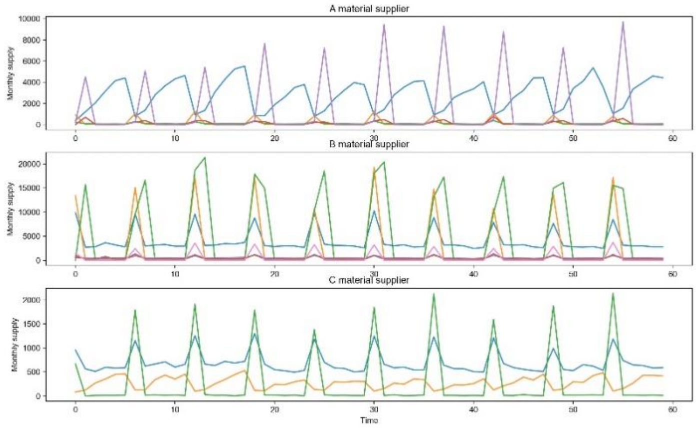


Figure 1 The relationship between the monthly supply and time of some suppliers

It can be seen from Figure 1 that the supplier's supply has a certain periodicity and the cycle is 24 weeks, which is consistent with the company's scheduled cycle[9]. From this, the weekly supply of each enterprise in a cycle can be roughly estimated. The calculation method of the supply quantity of the i-th week in the j-th enterprise cycle is as follows:

$$G_{ij}^{*}=\frac{\sum_{m=1}^{10} g_m}{10} \tag{3}$$

Among them, $g_m$ represents the supply quantity of the j-th company in the m-th cycle of the i-th week, i=1, 2, …,24, j=1,2,…,402, m=1,2,…,10 , i represents the number of weeks in a cycle, j represents the supplier number, and m represents the number of cycles.

Through this method, the estimated weekly supply of each enterprise in a cycle can be obtained, which can provide data support for subsequent problem solving. Next, establish the objective function and formulate the constraints.

(1) Objective function establishment:

To solve this resource allocation problem, 0-1 integer programming is preferred.

Since it is necessary to assign the least number of suppliers to the enterprise, let

, the objective function thus established is:

$$\min_{i} \sum_{i=1}^{402} y_i \tag{4}$$

(2) Restrictions:

Assuming that the company has a two-week inventory of 56,400 cubic meters, no matter how much the supply in the first two weeks is, it can guarantee to meet the production demand. The weekly production capacity of the enterprise is 28,200 cubic meters, and each cubic meter of product needs to consume 0.6 cubic meters of Class A raw materials, or 0.66 cubic meters of Class B raw materials, or 0.72 cubic meters of Class C raw materials. The constraints can be written:

$$\frac{\sum_{j=1}^{2} x_{ij}^{A}}{0.6}+\frac{\sum_{j=1}^{2} x_{ij}^{B}}{0.66}+\frac{\sum_{j=1}^{2} x_{ij}^{C}}{0.72}\geq 0 \tag{5}$$

Among them, $x_{ij}^{m}$ represents the supply quantity of the ith supplier in the jth week, and the superscript m represents the category of raw materials supplied by the supplier, i=1, 2, …,402, j=1, 2, …,24, m= A, B, C.

Due to the possibility of reducing the inventory, in order to meet the production demand, it is necessary to ensure that there are enough raw materials in each stage of the cycle, thus obtaining the constraints:

$$\frac{\sum_{j=3}^{N} x_{ij}^{A}}{0.6}+\frac{\sum_{j=3}^{N} x_{ij}^{B}}{0.66}+\frac{\sum_{j=3}^{N} x_{ij}^{C}}{0.72}+56400-28200\times N\geq 0 \tag{6}$$

Among them, N represents the number of consecutive weeks of investigation, N=3, 4, …,24.

This creates a 0-1 model that solves the least supplier:

$$\min_{i} \sum_{i}^{402} y_i$$

$$s.t.\begin{cases} y_i\in\{0,1\} & \text{i=1,2,...,402} \\ \frac{\sum_{j=1}^{2} x_{ij}^{A}}{0.6}+\frac{\sum_{j=1}^{2} x_{ij}^{B}}{0.66}+\frac{\sum_{j=1}^{2} x_{ij}^{C}}{0.72}\geq 0 & \text{i=1,2,...,54 , j=1,2,...,24} \\ \frac{\sum_{j=3}^{N} x_{ij}^{A}}{0.6}+\frac{\sum_{j=3}^{N} x_{ij}^{B}}{0.66}+\frac{\sum_{j=3}^{N} x_{ij}^{C}}{0.72}+56400-28200\times N\geq 0 & \text{N=3,4, . . . ,24} \end{cases} \tag{7}$$

Among them, $x_{ij}^{m}$ represents the supply quantity of the i-th supplier in the j-th week, and the superscript m represents the category of raw materials supplied by the supplier, m=A, B, C.

Using Matlab to solve this model, the minimum number of suppliers is 54. A score derived from the TOPSIS entropy weight method to establish a supplier determination model:

$$\max_{i} \sum_{i=1}^{402} y_i s_i$$

$$s.t.\begin{cases} y_i\in\{0,1\} & \text{i=1,2, . . . , 402} \\ \sum_{i=1}^{402} y_i = 54 & \\ \frac{\sum_{j=1}^{2} x_{ij}^{A}}{0.6}+\frac{\sum_{j=1}^{2} x_{ij}^{B}}{0.66}+\frac{\sum_{j=1}^{2} x_{ij}^{C}}{0.72}\geq 0 & \text{j=1,2, . . . ,24} \\ \frac{\sum_{j=3}^{N} x_{ij}^{A}}{0.6}+\frac{\sum_{j=3}^{N} x_{ij}^{B}}{0.66}+\frac{\sum_{j=3}^{N} x_{ij}^{C}}{0.72}+56400-28200\times N\geq 0 & \text{N=3, 4, . . . ,24} \end{cases} \tag{8}$$

Among them, $S_i$ represents the score of the i-th supplier, $x_{ij}^{m}$ represents the supply quantity of the i-th supplier in the j-th week, and the superscript m represents the category of raw materials supplied by the supplier, m=A, B, C.

After solving, 54 specific suppliers are obtained, and the 54 suppliers are classified and summarized according to raw materials A, B, and C. The results are shown in Table 4.

Table 4 At least 54 suppliers selected

| type | A | B | C |
|---|---|---|---|
| enterprise | S143, S037, S055, S064, S108, S114, S115, S126, S131, S151, S157, S194, S268, S282, S284, S291, S292, S306, S308, S340, S395 | S046, S078, S123, S139, S140, S152, S189, S201, S221, S229, S237, S247, S275, S307, S329, S352, S365, S374 | S005, S007, S031, S066, S075, S150, S266, S269, S330, S338, S348, S356, S361, S364, S367 |

### 2.2.2 Model establishment and solution of ordering plan

For the suppliers obtained above, formulate the most economical weekly raw material ordering plan for the company in the next 24 weeks. Based on the cost of Class C raw materials, comprehensive consumption and purchase price, the cost of raw materials is obtained, as shown in Table 5.

Table 5 Raw material costs

| type of enterprise | A | B | C |
|---|---|---|---|
| Inventory costs | 0.6 | 0.66 | 0.72 |
| purchase cost | 1.2 | 1.1 | 1 |
| overall costs | 0.72 | 0.726 | 0.72 |

(1) Objective function establishment:

Since there will be discrepancies between the supplier's supply of raw materials and the company's actual order quantity, we quantify it as the average satisfaction $\bar{F_i}$ when formulating the index, and include the average satisfaction in considering the ordering plan. In one cycle, Note that the company's order quantity for the i-th supplier in the j-th week is $x_{ij}$ , $X=[x_{ij}]_{54\times24}$; and the i-th supplier's satisfaction to the enterprise in the j-th week is $\bar{F}_{ij}$, $F=[F_{ij}]_{54\times24}$. The order quantity considers the average satisfaction i.e. $x_{ij}^*=\frac{x_{ij}}{F_{ij}}$, $X^*=\frac{X}{F}$.

According to the cost, based on the most economical ordering scheme, establish the objective function:

$$\min_{i,j}\ 0.72\sum_{i\in A}\sum_{j=1}^{24}x_{ij}^{*A}+0.726\sum_{i\in B}\sum_{j=1}^{24}x_{ij}^{*B}+0.72\sum_{i\in C}\sum_{j=1}^{24}x_{ij}^{*C} \tag{9}$$

Among them, $x_{ij}^{*m}$ represents the order quantity of the company considering the satisfaction of the i-th supplier in the j-th week, and the superscript m represents the category of raw materials, i =1, 2, …,34, j=1, 2, …,24, m =A, B, C.

(2) Restrictions:

First of all, the order quantity of the enterprise should be less than the supply capacity of the supplier, and the supply capacity should take the estimated supply quantity in 2.2.1. Denote the supply capacity of the jth supplier in the ith week as $G_{ij}^*$, $G=\{G_{ij}^*\}_{54\times24}$, and get the constraints: $0\le X^*\le G$.

For the remaining constraints, refer to the aforementioned 0-1 planning, and consider the average satisfaction level to obtain the final model of the most economical ordering plan:

$$\min_{s}\ \ S=0.72\sum_{i\in A}\sum_{j=1}^{24}x_{ij}^{*A}+0.726\sum_{i\in B}\sum_{j=1}^{24}x_{ij}^{*B}+0.72\sum_{i\in C}\sum_{j=1}^{24}x_{ij}^{*C} \tag{10}$$

$$s.t.\begin{cases}\dfrac{\sum_{j=1}^{2}x_{ij}^{A}}{0.6}+\dfrac{\sum_{j=1}^{2}x_{ij}^{B}}{0.66}+\dfrac{\sum_{j=1}^{2}x_{ij}^{C}}{0.72}\ge0 & \text{i=1,2,...,54 , j=1,2,...,24}\\ \dfrac{\sum_{j=3}^{N}x_{ij}^{A}}{0.6}+\dfrac{\sum_{j=3}^{N}x_{ij}^{B}}{0.66}+\dfrac{\sum_{j=3}^{N}x_{ij}^{C}}{0.72}+56400-28200\times N\ge0 & \text{N=3,4, . . . ,24}\end{cases} \tag{11}$$

Among them, $x_{ij}^{*m}$ represents the order quantity of the company considering the satisfaction of the i-th supplier in the j-th week, the superscript m represents the category of raw materials, m=A, B, C, G represents the supplier's supply capacity.

### 2.2.3 Model establishment and solution of transshipment scheme

The following is a transshipment plan with the least loss based on the order plan obtained from the solution. Visualize the data, as shown in Figure 2.

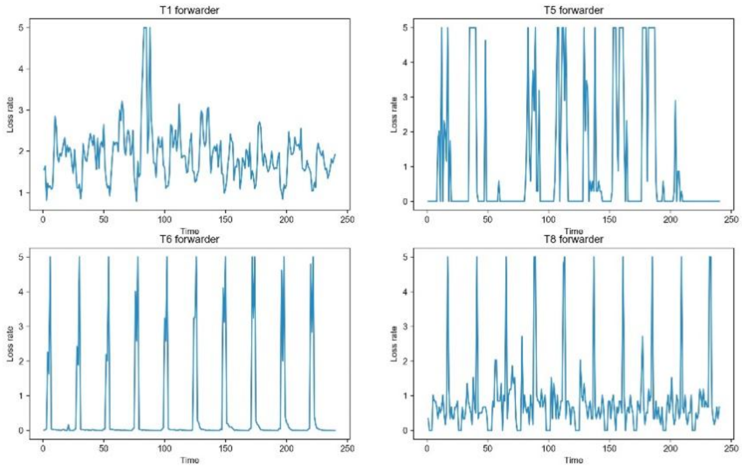


Figure 2 Transportation loss rate of some forwarders

The analysis shows that the transport loss rate also has a period of 24 weeks. Calculate the weekly average loss rate $L_{mj}$ of each forwarder according to the cycle, as the loss rate when formulating the forwarding plan. This is an optimization problem, and the objective function and constraints are examined below.

(1) Objective function establishment:

There is a choice of forwarders in the transfer process. Similar to the above, a 0-1 integer programming is used.The established objective function is:

$$\min_{t} \ \text{t}=\sum_{i}\sum_{j=1}^{24} x_{ij}^{*} L_{mj} z_{m} \tag{12}$$

Among them, $x_{ij}^{*m}$ is the order quantity of the enterprise considering the satisfaction of the i-th supplier in the j-th week, and $L_{mj}$ is the loss rate of the m-th forwarder in the j-th week.

(2) Restrictions:

$$\sum_{\text{Transshipment by m forwarder}} x_{ij}^{*} \leq 6000 \tag{13}$$

Combined with the constraints of the number of transporters and the 0-1 variable, the minimum loss transport model is finally obtained:

$$\min_{t} \ \text{t}=\sum_{i}\sum_{j=1}^{24} x_{ij}^{*} L_{mj} z_{m}$$

$$st.\begin{cases} \sum\limits_{\text{Transshipment by m forwarder}} x_{ij}^{*} \leq 6000 \\ z_{m} \in \{0,1\}, m=1,2,\ldots,8 \\ \sum\limits_{m-1}^{8} Z_{m} \leq 8 \end{cases} \tag{13}$$

Among them, $x_{ij}^{*m}$ is the order quantity of the company considering the satisfaction of the ith supplier in the j-th week, $L_{mj}$ is the loss rate of the m-th forwarder in the j-th week, and $z_{m}$ is a 0-1 variable. In the calculation, the greedy algorithm is used to solve the problem[10], that is, the current optimal point is selected each time. If the conditions are not met, the second advantage can be selected.

### 2.2.4 Implementation effect analysis

See Table 6 below for an analysis of the results for the ordering program.

Table 6 Analysis of the results of the ordering plan Order plan result analysis

| Production status | Production needs can be met every week | |
|---|---|---|
| Inventory | scope | [22397,96957] |
| | mean | 59540 |
| | mean square error | 222.67 |

The average value of the inventory is close to the production demand of two weeks, which can guarantee the normal production and operation activities, and will not put pressure on the inventory, cause inventory backlog, and increase the cost. It is a more reasonable ordering plan.

Because when solving the transshipment plan, the priority of the condition that "the raw materials supplied by one supplier every week should be transported by one transhipper as much as possible" is prioritized, in addition to the suppliers with more than 6,000 orders corresponding to multiple transhippers, there are also Suppliers with an order volume of less than 6,000 correspond to multiple forwarders. The analysis of the transport scheme is shown in Table 7:

Table 7 Analysis of the results of the transshipment plan

| | |
|---|---|
| Average attrition rate | 8.33% |
| Proportion of suppliers of being transshipped by multiple transshippers | 3.85% |

The average loss rate of the transshipment scheme is moderate, and the proportion of one supplier corresponding to multiple transshippers is also small. It is a more reasonable transshipment scheme with the smallest loss rate.

## 3. Conclusions

This paper defines the evaluation index scientifically and reasonably, and the data related to the index is easy to obtain. After the data is obtained, it is processed in a consistent and dimensionless manner, which overcomes the problem of inconsistency of various data units and makes the evaluation process more standardized, objective and unified. In order to avoid the influence of subjective evaluation on the real situation, this paper uses the entropy weight method and the relevant knowledge of membership degree to scientifically and reasonably determine the weight coefficient of each evaluation index, which makes the establishment of the entire evaluation model more reasonable and accurate.

First of all, the evaluation indicators are reasonably and comprehensively selected and a comprehensive evaluation model based on the TOPSIS entropy weight method is established. The six indicators are comprehensively analyzed to avoid the influence of subjective evaluation on the real situation, and the scientific and reasonable determination of the evaluation indicators The weight coefficient makes the establishment of the entire evaluation model more reasonable and accurate; secondly, taking a cycle of 24 weeks as the research object, the problem is refined, the error is reduced, and the implementation effect is analyzed from multiple angles, and the model has a good promotion.

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