

Research on raw material ordering and transportation scheme of production enterprises based on genetic algorithm

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Abstract. With the deepening of China's reform and opening up and the gradual improvement of productivity level, the production enterprises of construction and decoration panels have gradually sprung up. In order to improve the production efficiency of enterprises and reduce the loss of raw materials, this paper establishes an analytical hierarchical model, and a 0-1 goal programming model. Based on the analysis of the problem, it pays attention to the connection between the questions. A rational solution for ordering and transporting raw materials based on the 0-1 goal programming model is also proposed in conjunction with real-life practice. In this paper, the problem is solved by building several mathematical models and the results are entered in Annex A and Annex B. After the model is implemented and tested, significant improvements are found. In addition, the model is improved by a genetic algorithm so that the model is well applicable and generalizable.

Keywords: 0-1 programming model, analytical hierarchy process, genetic algorithm, raw material ordering.

1. Research background

With the deepening of China's reform and opening up and the gradual improvement of productivity level, enterprises manufacturing construction and decoration plates have gradually emerged. In order to improve the production efficiency of enterprises and reduce the loss of raw materials, multiple reasonable solutions for production enterprises are needed for ordering and transferring raw materials to meet the needs of the most economical production and minimal transfer loss rate. Thus, a higher level of supply chain management can be achieved, so that raw material losses are minimized and customer satisfaction is achieved.

1.1. Problems that need to be addressed

1.1.1 Conditions obtained from the analysis of the question

(1) The production process of this enterprise is divided into two stages (see Figure 1). In the first stage, the enterprise provides the order quantity to the supplier, after which the supplier prepares the supply quantity according to the enterprise's order quantity, and there may be errors directly between the two. In the second stage, the supplier delivers the ordered raw materials to the production enterprise through a forwarder and the enterprise acquires them all, where there is a consumption rate during the forwarding process. In addition, the company's raw material inventory meets the two-week production demand as much as possible.

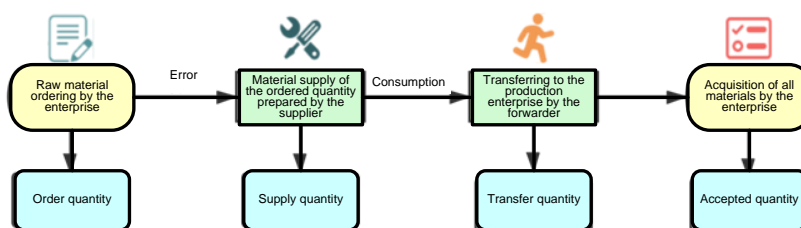


Figure 1. Flow chart of ordering and shipping

(2) The production company needs to consume raw materials of category A,B or C to produce products with a production capacity of 28, 200 cubic meters per week. 0.6 cubic meters of raw materials of category A or 0.66 cubic meters of raw materials of category B or 0.72 cubic meters of raw materials of category C are required for each cubic meter of products. In addition,the unit purchasing price of raw materials in category A is 20% higher than that of raw materials in category C,and the unit purchasing price of raw materials in category B is 10% higher than that of raw materials in category C,respectively.

(3) In general,raw materials supplied by one supplier are transported by one forwarder per week,and in addition,the transport capacity of each forwarder is 6, 000 cubic meters per week.

2. Model building and solving

2.1. Model building and solving

2.1.1 Model building

Quantitative analysis of supply characteristics is one of the important elements in measuring and evaluating ordering solutions. From the data analysis and data mining in Annex 1,we summarized six model indicators from the perspectives of both enterprises and suppliers,in accordance with the enterprise recognition index and supplier strength index. These indicators are the order stability of the jth supplier the frequency of ordering from the jth supplier the total amount of ordering from the jth supplier by the enterprise the difference in supply from the jth supplier in the i-th week Y_{ij} ,the maximum supply from the jth supplier and the degree of supply completion σ_j . Then,based on analytic hierarchy process,we analyzed the influence of the above six factors on the criterion of "importance of guaranteeing enterprise production" and constructed a reasonable mathematical equation.

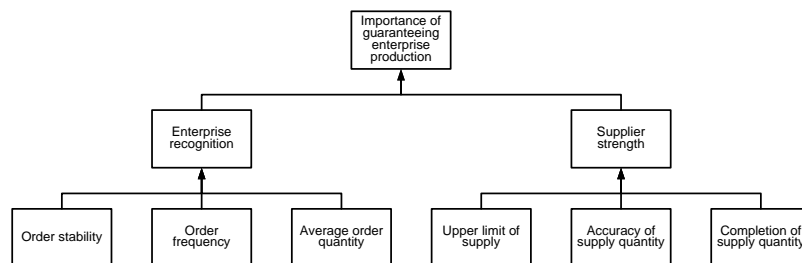


Figure 2. Constructed model of importance of guaranteeing enterprise production by analytic hierarchy process

2.1.2 The perspective of production enterprises

The order stability of the enterprise at the jth supplier is represented by the variance ϵ_j : In general,the smaller the variance,the more stable it indicates,and the higher the company's recognition of the supplier. From this,we obtain equation (1) as follows:.

$$\epsilon_j = \frac{\sum_{i=1}^{402} (D_{ij} - \bar{D}_{ij})^2}{402} \tag{1}$$

According to the data in Annex 1,the variance of the company's orders from each supplier is calculated using mathematical software in a line chart,as shown in Figure 3.

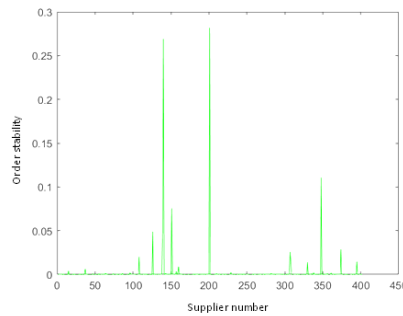


Figure 3. Variance line graph of ordering from suppliers

Frequency of enterprises ordering from the j th supplier α_j : Generally speaking, the higher the ordering frequency, the greater its importance and the higher the recognition of the supplier by the enterprise. A higher ordering frequency not only brings great convenience and economic benefits to enterprises in terms of ordering, but also facilitates the establishment of long-term cooperation relationships and facilitates the sustainable development of enterprises.

$$D_{ij}(i = 1, 2 \dots 240, j = 1, 2 \dots 402) > 0 \tag{2}$$

Then it is noted that the enterprise orders from this supplier and the loop factor e is self-adding, whereupon we define equation (3) as follows:

$$\alpha = \frac{e}{n} \tag{3}$$

After processing and mining the data, we obtained indicators to evaluate the recognition of the enterprise to the supplier, the supply frequency of each supplier, and drew a line graph, as shown in Figure 4.

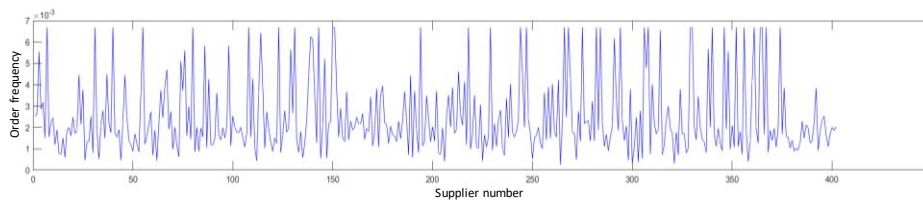


Figure 4. Supply frequency line graph of suppliers

Total amount ordered by the enterprise at the j th supplier W_j : In general, the larger the total amount ordered at the j th supplier, the higher the recognition of that supplier by the production enterprise. Thus, we defined equation (4) as follows:

$$W_j = \sum_{i=1}^{240} D_{ij} \tag{4}$$

Where the average total order quantity (w denotes the times of orders) is expressed as follows:

$$W_{wj} = \frac{\sum_{i=1}^{240} D_{ij}}{w} \tag{5}$$

To facilitate data visualization, we converted the vertical coordinates to average total order quantity W_{wj} and used the mathematical software Matlab to draw a line graph of average order quantity versus suppliers, as shown in Figure 5.

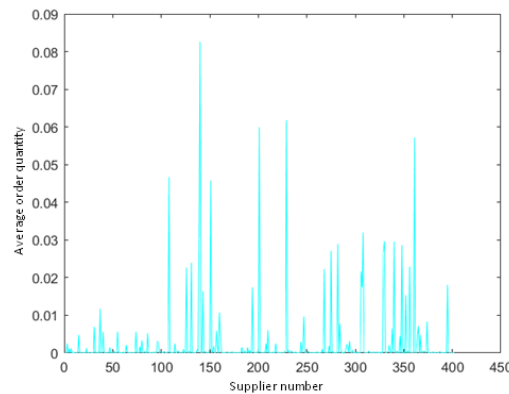


Figure 5. The line graph of average order quantity at suppliers

2.1.3 Supplier perspective

supplier in the i th week: If the supply difference Y_{ij} tends to 0, it means that the supply of the j th supplier is close to the amount ordered by the enterprise. The higher the accuracy of the supplier's supply, it will neither cause the phenomenon of inadequate supply nor cause too much supply, which leads to the enterprise's backlog of raw materials. From this we obtained equation (6) as follows:

Through the data mining and topic analysis of Annex I, we obtained the supplier strength evaluation index, the supply difference or the absolute value of the difference between the supply quantity and the order quantity, which is used to evaluate the supplier's understanding of the enterprise, the supplier's order completion degree, and analyze the supplier strength from the whole. After data visualization, the average supply difference of each supplier was obtained, as shown in Figure 6.

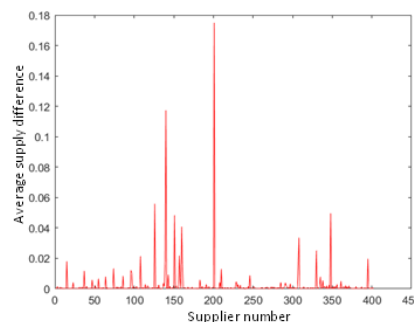


Figure 6. Line graph of suppliers' average supply difference

Maximum supply quantity of the j th supplier M_j : Through the data processing in Annex I, we compared the single maximum supply quantity of each supplier as the upper limit of the supplier's supply quantity. The higher the upper limit of the supplier's supply quantity, the greater the supply elasticity of the supplier and the lower the probability of insufficient goods. Thus, we obtained the equation (6) as follows:

$$M_j = \max G_{ij} (j = 1, 2 \dots 402) \tag{6}$$

The maximum supply quantity of each supplier was counted in the data in Annex 1 as the upper limit of supply to evaluate the business strength of suppliers, and a line graph was obtained, as shown in Figure 7.

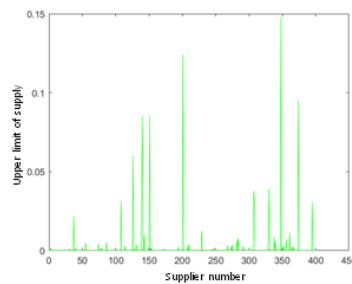


Figure 7. Line graph of upper limit of supply

Supply completion of the j th supplier σ_j : The degree of supply completion of each supplier is a measure of the strength of the supplier. If the supplier completes a higher degree, it indicates that the supplier is stronger and operates well, and that the enterprise has a higher intention to cooperate. Therefore, we wrote a loop algorithm using mathematical software (see Appendix II for the procedure), setting the loop factor $e = 0$.

If:

$$\frac{G_{ij}(i=1,2\dots240; j=1,2\dots402)}{D_{ij}(i=1,2\dots240; j=1,2\dots402)} \geq 1 \quad (7)$$

Then the d this supply and the loop factor e is self-adding, whereupon we defined equation (7) as follows:

Based on the data processing in Annex 1, the average supply completion degree of 402 suppliers was obtained, as shown in Figures 8, as a factor to evaluate the strength of suppliers.

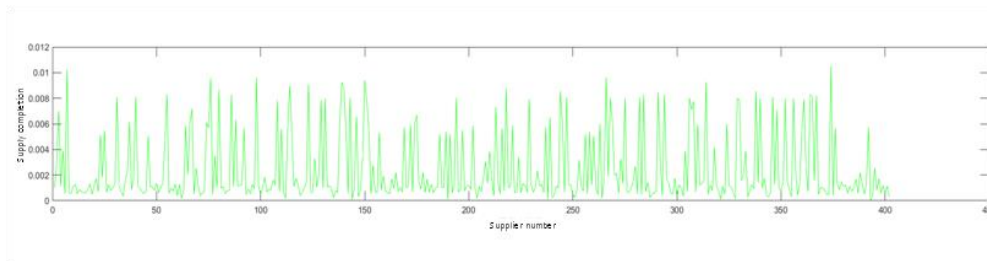


Figure 8. Supply completion by suppliers

3. Model solving

3.1. Model solving for Question 1

For the two aspects of enterprise recognition and supplier strength, the main purpose of the enterprise is to meet the production demand and cooperate with the supplier continuously. The main purpose of suppliers is to improve their supply strength. In relation to these two factors, we consider them to be equally weighted, thus obtaining a pairwise comparison matrix of the importance of enterprise factors and supplier factors for "guaranteeing enterprise production":

$$Q_1 = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \quad (8)$$

$$Q_2 = \begin{bmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 3 \\ 1/2 & 1/3 & 1 \end{bmatrix} \quad (9)$$

From the perspective of enterprise recognition, the main purpose of enterprises is to choose the right supplier to meet production needs. For the average order quantity and ordering frequency, the average order quantity is given higher weight. Considering that some of them have a low frequency of ordering but high stability and have not been cooperated by enterprises for a long time, the ordering frequency is given a higher weight than the ordering stability. Similarly, the average order quantity is

given a higher weight than the ordering stability. According to the idea of analytic hierarchy process and Satty's criterion, we obtained the pairwise comparison matrix of order stability, ordering frequency and average order quantity for the enterprises:

$$Q_2 = \begin{bmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 3 \\ 1/2 & 1/3 & 1 \end{bmatrix} \quad (10)$$

$$Q_3 = \begin{bmatrix} 1 & 1/5 & 1/4 \\ 5 & 1 & 2 \\ 4 & 1/2 & 1 \end{bmatrix} \quad (11)$$

From the perspective of supplier strength, the purpose of the supplier is to make an accurate judgment on the order quantity of the enterprise. Therefore, the weight of supply accuracy is higher than the upper limit of supply, the weight of supply completion is higher than that of the upper limit of supply, and the weight of supply completion is higher than that of supply accuracy. According to the analytic hierarchy process, we obtained a pairwise comparison matrix of the upper limit of supply, accuracy of supply, and completion of supply to suppliers:

$$Q_3 = \begin{bmatrix} 1 & 1/5 & 1/4 \\ 5 & 1 & 2 \\ 4 & 1/2 & 1 \end{bmatrix} \quad (12)$$

Each pairwise comparison matrix was first normalized, and then Matlab was used to calculate each corresponding eigenroot and eigenvector:

$$\omega_1 = (0.5, 0.5)^T, \varphi_1 = 2 \quad (13)$$

$$\omega_2 = (0.2970, 0.5396, 0.1634)^T, \varphi_2 = 3.0092 \quad (14)$$

$$\omega_3 = (0.0974, 0.5695, 0.3331)^T, \varphi_3 = 3.0246 \quad (15)$$

The individual pairwise comparison matrices were tested to pass the consistency test and the results were reliable. The final equation for the importance of guaranteeing enterprise production was derived as the following equation (5-7):

$$N = 0.2848\theta_j + 0.2698\alpha_j + 0.1665W_{wj} + 0.1485\sigma_j + 0.0817\epsilon_j + 0.0487M_j \quad (5-7) \quad (16)$$

Where, \hat{M}_j are normalized outcomes of M_j .

3.2. Model building and solution of Question 2

3.2.1 Analysis for the first sub-question of Question 2

It is known from the question that on the basis of the 50 suppliers selected in Question 1, the minimum number of suppliers for the purpose of meeting the production conditions was selected. For this purpose, model ① was developed

3.2.1.1 Preparation before model building

From the analysis of the results of Question 1, it is clear that the 50 important suppliers contain 14 suppliers who provide materials in Category A, 16 suppliers who provide materials in Category B, and 20 suppliers who provide materials in Category C. The 50 suppliers were rearranged in the corresponding material categories, according to the size of the serial number. It is assumed that the company receives $a_i (i = 1, 2 \dots 14)$ for materials of Category A, $b_i (i = 1, 2 \dots 16)$ for materials of Category B, and $c_i (i = 1, 2 \dots 20)$ for materials of Category C.

Using 0-1 programming ^[1], 50 supplier companies were labeled by serial number, and expressed as $x_i (i = 1, 2 \dots 50)$, where $x_i = 1$ means the company cooperated with the supplier, and $x_i = 0$ means the company did not cooperate with the supplier.

According to the known conditions of the question, each cubic meter of product consumes 0.6 cubic meters of raw materials of Category A, or 0.66 cubic meters of raw materials of Category B, or 0.72 cubic meters of materials of Category C. The equation for converting each cubic meter of different types of raw materials into finished products is:

Category A:

$$\frac{1}{0.6} = 1.667 \quad (17)$$

Category B:

$$\frac{1}{0.66} = 1.515 \quad (18)$$

Category C:

$$\frac{1}{0.72} = 1.389 \quad (19)$$

Thus, the raw materials of categories A, B and C per cubic meter can be converted into the products of 1.667 cubic meters, 1.515 cubic meters and 1.389 cubic meters.

3.2.1.2 Model ① building - minimum suppliers (selected among 50 suppliers in Question 1)

The 0-1 programming model is as follows:

$$\min M = \sum_{i=1}^{14} X_i + \sum_{j=1}^{16} Y_j + \sum_{q=1}^{20} Z_q \quad (20)$$

Where, $i = 1, 2, \dots, 14, j = 1, 2, \dots, 16, q = 1, 2, \dots, 20$

$$s. t. \left\{ \begin{array}{l} 95\% \times \left(\frac{a_i \times X_{14 \times 24}}{0.6} + \frac{b_j \times Y_{16 \times 24}}{0.66} + \frac{c_q \times Z_{20 \times 24}}{0.72} \right) \geq \left[\begin{array}{l} 5.64 \times 10^4 \\ 2.82 \times 10^4 \\ \dots \\ 2.82 \times 10^4 \end{array} \right] \\ i = 1, 2, \dots, 14, j = 1, 2, \dots, 16, q = 1, 2, \dots, 20; \\ a_i + b_j + c_q \leq 6000, (i = 1, 2, \dots, 14, j = 1, 2, \dots, 16, q = 1, 2, \dots, 20) \\ \sum_{j=1}^8 x(i, j) \leq 1, (i = 1, 2, \dots, 50) \\ \sum_{j=1}^8 g(i) * x(i, j) \leq 6000, (i = 1, 2, \dots, 50, j = 1, 2, \dots, 8) \\ x_i, y_j, z_q \in \{0, 1\}, (i = 1, 2, \dots, 14, j = 1, 2, \dots, 16, q = 1, 2, \dots, 20) \\ a_i = 95\% * G * \tau_i, (i = 1, 2, \dots, 14, j = 1, 2, \dots, 16, q = 1, 2, \dots, 20) \\ b_j = 95\% * G * \tau_j, (i = 1, 2, \dots, 14, j = 1, 2, \dots, 16, q = 1, 2, \dots, 20) \\ c_q = 95\% * G * \tau_q, (i = 1, 2, \dots, 14, j = 1, 2, \dots, 16, q = 1, 2, \dots, 20) \end{array} \right. \quad (21)$$

3.2.1.3 Model ② building - minimum suppliers (selected among 402 suppliers)

(1) Description of symbols

$A_{146 \times 24}$ — Supply quantity matrix for materials of Category A

$B_{134 \times 24}$ — Supply quantity matrix for materials of Category B

$C_{122 \times 24}$ — Supply quantity matrix for materials of Category C

N_A — Decision matrix for materials of Category A

N_B — Decision matrix for materials of Category B

N_C — Decision matrix for materials of Category C

Firstly, the data in Annex 1 were divided into 10 groups every 24 pieces as a period, and the average value was calculated. By drawing a graph in Matlab, we can get that the type of material ordered by the company has a certain periodicity, as shown in Figure 5-8.

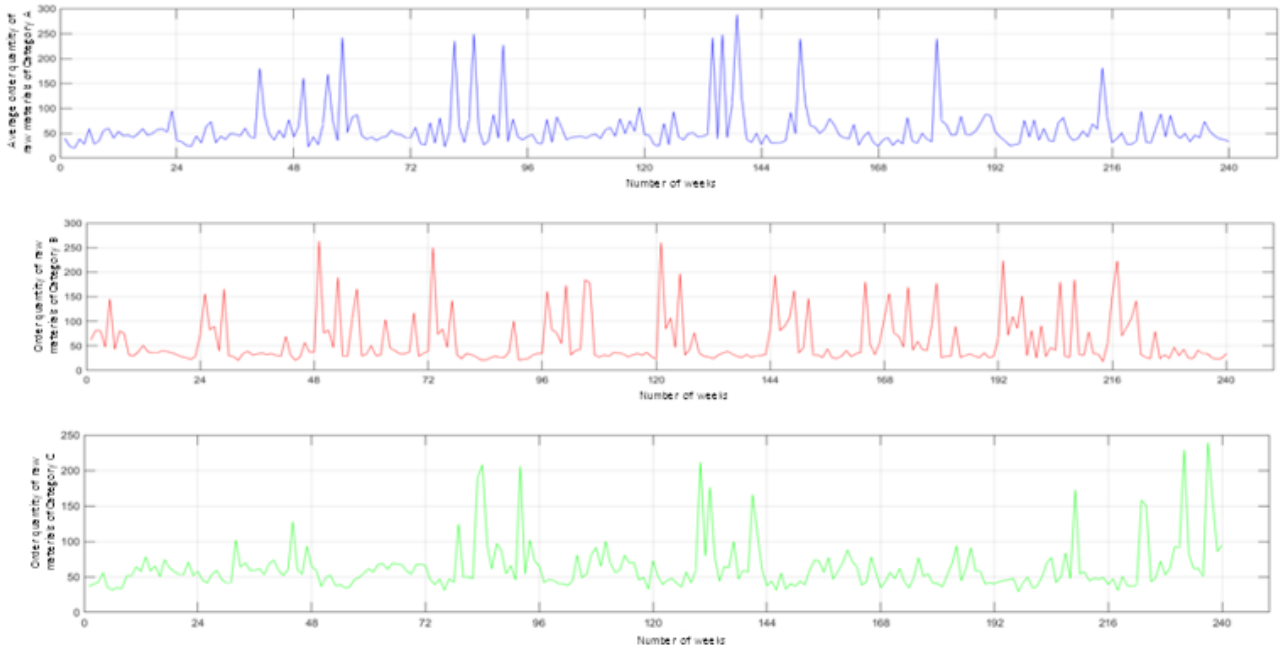


Figure 9. Line graph of the order quantity of raw materials of categories A, B and C

It is assumed that the quantity supplied by each supplier to the company is the average of each cycle. Therefore, the supply quantity of each supplier can be determined and represented by matrix A. In this case, there are 146 suppliers supplying materials of Category A, with a cycle time of 24. Therefore, the matrix A with 146*24 was constructed as shown below.

$$A_{146 \times 24} = \begin{bmatrix} 1 & 0 & \cdots & 1 \\ 5556 & \cdots & 79 & \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} \quad (22)$$

Similarly, we can also obtain the following matrices:

$$B_{134 \times 24} = \begin{bmatrix} 1 & 0 & \cdots & 1 \\ 3449 & \cdots & 36 & \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} \quad (23)$$

$$C_{122 \times 24} = \begin{bmatrix} 1 & 0 & \cdots & 1 \\ 5863 & \cdots & 77 & \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} \quad (24)$$

(2) Objective function analysis

The minimum number of suppliers is the sum of the suppliers of raw materials of categories A, B and C when the production conditions of the enterprise are met, and the data from each of the 24 groups of data selection matrices were summed to obtain the objective function as follows:

$$\min M = \sum_{i=1}^{24} (N_A)_{ij} + \sum_{i=1}^{24} (N_B)_{ij} + \sum_{i=1}^{24} (N_C)_{ij} \quad (25)$$

(3) Constraints

① Production volume constraint

In order to ensure the production of the enterprise, the inventory in the first week is assumed to be 0, and the question requires the preparation of raw materials for two weeks of capacity in each week. Therefore, 2.82*2= 56,400 cubic meters of raw materials need to be prepared in the first week. To ensure production, the maximum consumption rate in Annex 2 is 5%. To ensure production, we have a transfer efficiency of 95%. Thus the following constraints are obtained:

$$95\% \times \left(\frac{N_A \times A_{146 \times 24}}{0.6} + \frac{N_B \times B_{134 \times 24}}{0.66} + \frac{N_C \times C_{122 \times 24}}{0.72} \right) \geq \begin{bmatrix} 5.64 \times 10^4 & & & \\ & 2.82 \times 10^4 & & \\ & & \dots & \\ & & & 2.82 \times 10^4 \end{bmatrix} \quad (26)$$

②0-1 variable constraint for supplier selection, i.e.

$$N_A, N_B, N_C \in \{0, 1\} \quad (27)$$

Combining the above analysis, the model is derived as follows:

$$\min M = \sum_{i=1}^{24} (N_A)_{ij} + \sum_{i=1}^{24} (N_B)_{ij} + \sum_{i=1}^{24} (N_C)_{ij} \quad (28)$$

$$s. t. \begin{cases} 95\% \times \left(\frac{N_A \times A_{146 \times 24}}{0.6} + \frac{N_B \times B_{134 \times 24}}{0.66} + \frac{N_C \times C_{122 \times 24}}{0.72} \right) \\ \geq \begin{bmatrix} 5.64 \times 10^4 & & & \\ & 2.82 \times 10^4 & & \\ & & \dots & \\ & & & 2.82 \times 10^4 \end{bmatrix} \\ N_A, N_B, N_C \in \{0, 1\} \end{cases} \quad (29)$$

4. Conclusion

The 0-1 programming model was used several times in the model to solve the problem, which fits with the research content of this paper, and the model has good reasonableness. Due to the powerful functions of Lingo and Matlab software, the computer running time was greatly reduced, the objective function and constraints given in the question were visually reflected, and the optimal solution of the model was obtained by various methods, which illustrated the correctness and applicability of the model. For this problem, an AHP model was established by data mining, determining the evaluation criteria, and continuously changing the objective function. The 0-1 programming model was applied for optimization. With the help of Lingo and Matlab mathematical software, we reduced labor, saved time, and provided reference experience for building a more reasonable mathematical model for similar problems. The optimization model developed is closely related to life, combining practical situations and taking into account both general and specific situations in a well-planned manner. This model can be used in the production supply chain, so this model is practical and generalizable. Therefore, the results in this paper can be generalized to similar environments in life. Since the use of the fuzzy comprehensive evaluation model based on the analytic hierarchy process is somewhat subjective, in order to improve its reliability, the data were introduced into the model for simulation several times to make the results more scientific and reliable.

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