ISSN: 2688-9323

Research on the Plan Decision-making of Ordering and Transportation of Raw Materials in Production Enterprises

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Abstract

With the rapid development of economies of scale in supply chains at this stage, upstream suppliers are a very important part of production enterprises. At the same time, in order to reduce transportation losses and warehousing costs, it is necessary to formulate reasonable and economical ordering plans and transportation plans in advance. In this paper, we construct an evaluation model and a multi-objective planning model by analyzing the order quantity, supply quantity and the loss rate of 8 forwarders of 402 suppliers in the past 240 weeks. Mathematical software determines the company's ordering and transshipment plan in the next 24 weeks, and analyzes and solves the problems of supplier selection, raw material ordering and transshipment selection for a production enterprise.

Keywords

Supply Chain; Weighted Topsis; Objective Planning; Sensitivity Analysis.

1. Research Background

Supply chain is a network chain structure involving the up and down circulation of products and services in the production process of an enterprise. It is crucial to the production process of an enterprise. At this stage, whether it is the production industry or the transportation industry, mastering the supply chain can master the main sources of information. You can make choices by understanding the source of raw materials and the basic situation of the transportation company, which will give the company priority in the market.

In this paper, we quantitatively analyze and rate the supply characteristics of 402 suppliers. Selecting the four categories of delivery status, raw material cost performance, supply capacity, and enterprise preference, and obtaining the cumulative delivery rate, delivery completion rate, product cost performance, supplier's maximum supply capacity, supplier average supply capacity. The standard deviation and preference of the quantity of supply demand can be achieved, and a total of seven indicators are used. The combination weighting Topsis method is used to establish an important mathematical model to ensure the production of the enterprise [4]. The combination weighting method uses the entropy weight method and the weight determined by the literature review. Matlab software programming to find out the top 50 companies.

Finding the minimum number of suppliers based on known information, establishing an integer 0-1 programming model. The total quantity is the objective function to obtain the minimum value, and the production requirements are used as constraints. Lingo software is used to solve the problem, and it is concluded that the enterprise needs at least 12 suppliers to meet the normal production requirements, formulating ordering and transshipment plans [5]. The planning models all use the cost of raw materials as the objective function to obtain the minimum value, and the relevant inventory and production demand are the constraints, establishing the relevant objective planning model, using the Matlab software to solve, and formulating a 24-week reasonable and economical ordering plan and transshipment plan.

The sum of raw materials is added as the objective function to obtain the minimum value, and the production demand, inventory, and the proportion of three types of raw materials are used as constraints. A dual-objective programming model is established, and Matlab software is used to solve the problem to obtain relevant ordering and transshipment plans.

Based on the available information, determine how much the company can increase its weekly production capacity and give 24 weekly ordering and transshipment plan, establishing the objective function of profit to find the maximum value, introducing sensitivity analysis into the constraints, establishing the target planning model, and using Matlab software programming to get the relevant order plan and transshipment plan.

2. Model Establishment and Solution

2.1. Supplier Evaluation Index System

The cumulative delivery rate is calculated as the ratio of the sum of the supplier's supply to the enterprise's order within 240 weeks, which can be expressed as:

$$G_j = \frac{\sum d_{ij}}{\sum x_{ij}} \cdot 100\% \tag{1}$$

where d_{ij} represents the supplier's deliveries, X_{ij} represents the order quantity of the enterprise.

The delivery completion rate is the ratio of the sum of the number of weeks that the supplier supplies the company to the sum of the number of weeks that the company orders from the supplier, which can be expressed as:

$$OTD_j = \frac{\sum wp_j}{\sum wd_j} \cdot 100\%, j = 1,2,3, \dots ,420 \tag{2}$$

where wp_j represents whether the supplier provides goods to the enterprise in the jth week, wd_j represents whether the company orders from the supplier in the jth week.

The price/performance ratio of the product is assigned as follows:

$$\text{A: } 1.2 \quad \text{B: } 1.1 \quad \text{C: } 1 \tag{3}$$

The maximum supply capacity of the supplier is the maximum supply quantity that the enterprise can provide under the demand of ordering from the supplier. The supplier's maximum supply capacity can represent the size of the supplier, and enterprises can choose when they need to order different quantities of goods.

The average supply capacity of a supplier is the average weekly supply that a company can provide when ordering from a supplier, which can be expressed as:

$$\overline{M_j} = \frac{\sum m_{ij}}{\sum wp_j} \tag{4}$$

where m_{ij} represents the weekly supply from different suppliers, $\sum wp_j$ represents the total number of weeks available.

Using the quantity supplied - the quantity ordered to get the standard deviation of the weekly unsupplied value corresponding to the value:

$$S_j = \frac{1}{n}\sqrt{(\overline{e_j} - e_{ij})^2} \tag{5}$$

where e_{ij} represents the average of the number of insufficient supplies.

The number of weeks of ordering from a business to a supplier is:

$$F_j = \sum wd_j \tag{6}$$

The more times an enterprise supplies a supplier, the more the enterprise trusts the supplier, and it also reflects the satisfaction of the supplier and the enterprise. Cooperation satisfaction has a decisive impact on the stability of cooperation, and the cooperation satisfaction is high. The supplier cooperation process is very satisfactory, so the willingness to continue cooperation will be stronger.

List the decision matrix: where a_{ij} is the ith metric for the jth supplier, which can be expressed as:

$$\mathrm{A} = \left[G_j, OTD_j, Ce, M_j, \overline{M_j}, S_j, F_j\right] \tag{7}$$

Performing forward processing, that is, subtract the other items from the largest item in the indicator:

$$S_j' = \max S - S_j \tag{8}$$

In order to clear the inconsistency of the dimension and the range of the data, so as to better carry out unified and intuitive comparison processing, all indicators are subjected to standard 0-1 transformation, so that the values in the matrix are all between 0-1, which can be expressed as:

$$x_{ij} = \frac{a_{ij} - \min a_j}{\max a_j - \min a_j} \tag{9}$$

2.2. Topsis Method

Determining the weight of the index, and use the combined weighting method to obtain the average weight according to the subjective method and the objective method [1].

According to the weight matrix of various indicators mentioned in the procurement and supply chain book [3], which can be expressed as:

$$w_1 = [0.2, 0.15, 0.051\ 0.1, 0.2, 0.2, 0.1] \tag{10}$$

Calculating the proportion of each evaluation object with respect to each index value, taking the delivery rate as an example:

$$h_{1j} = \frac{G_j}{\sum G_j} \tag{11}$$

Calculating the entropy value of each indicator:

ISSN: 2688-9323

$$e_i = -\frac{1}{\ln 7}\sum h_i \, lnh_i \tag{12}$$

Calculating the coefficient of variation for each metric:

$$g_i = 1 - e_i \tag{13}$$

Calculating the weight of each indicator:

$$w_i = \frac{g_i}{\sum g_i} \tag{14}$$

Calculated by MATLAB:

$$w_2 = [0.056, 0.022,0.06,0.444,0.33,0.001,0.082] \tag{15}$$

Final weight determination:

$$\mathrm{w} = \alpha \cdot w_1 + \beta \cdot w_2 \tag{16}$$

Because the index determined by the entropy weight method does not consider the actual meaning, and the relevant literature has certain convincing power, when determining the weight, it has $\alpha = 0.9, \beta = 0.1$.

For each supplier j, the corresponding score:

$$C_j = \frac{d_j^-}{d_j^- + d_j^+} \tag{17}$$

After solving and sorting using Matlab, the suppliers are obtained. The top 50 most important companies are listed as shown in table 1.

Table 1. The top 50 most important companies

ranking	1	2	3	4	5
supplier	S229	S108	S361	S348	S282

From table 1, it can be seen that among the top 50 suppliers, although the supply rate of some suppliers is very low, such as S348 and S201, these suppliers can meet some of the needs of enterprises to a certain extent, and may occasionally meet the needs of enterprises. The urgent needs of the enterprise, so such suppliers play a pivotal role, in line with the results obtained.

2.3. 0-1 Integer Programming Model

Purchasing within 24 weeks requires no less than 25 weeks of production demand, establishing constraints:

$$\sum U_A + \sum U_B + \sum U_C \geq 28200 \times 25 \tag{18}$$

where U represents the number of products that the enterprise can produce, and the subscript represents the products produced by different kinds of raw materials:

$$\mathrm{U} = \frac{x_j}{D} \tag{19}$$

where x represents the quantity of raw materials purchased by the company from the jth supplier, and D represents the quantity of raw materials required by unit product.

The selection of the cut-off point for outliers is to remove the influence of extreme values [2]. Adding 1.5 times the difference between the lower quartile and the lower quartile-upper quartile can be expressed as:

$$x_i = UQ_j + 1.5IQR_j \tag{20}$$

where TQ_j represents the lower quartile of the goods supplied by the jth supplier, UQ_j denotes the upper quartile of the goods supplied by the jth supplier, IQR_j is the difference between the lower quartile and the upper quartile, excluding the influence of extreme values,

This enables suppliers to provide more accurate and reasonable supply quantities. Because there are too many suppliers, only the first 8 are taken here, as shown in Fig. 1. It can be observed that the third and seventh ones are greatly affected by extreme values. During the calculation, it may be calculated that the value that the supplier can supply is too small, but the overall data will be more reasonable.

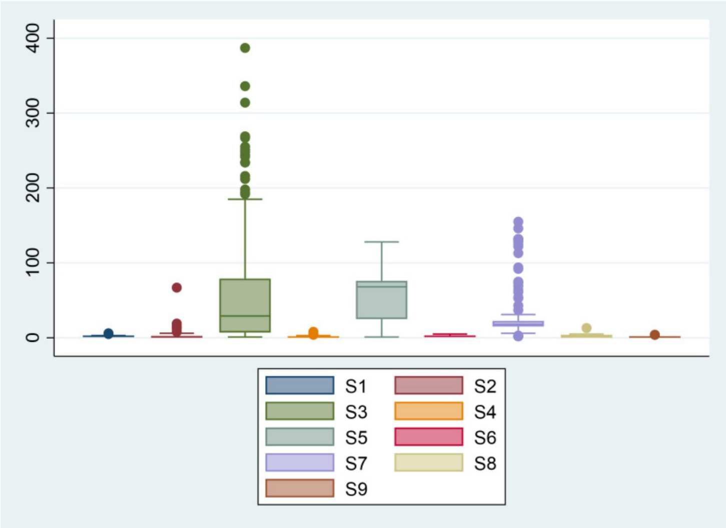

Figure 1. Boxplot of the ordering situation of the top 8 suppliers

The second constraint is that the purchase volume of the first week is required to meet the production demand of two weeks, that is, the raw material inventory that meets the production demand of the above-mentioned enterprises for two weeks or more as far as possible, which can be expressed as:

$$\sum U_{A_1}^{max} + \sum U_{B_1}^{max} + \sum U_{C_1}^{max} \geq 28200 \times 2 \tag{21}$$

where U_1^{max} indicates the maximum number of products a business can produce in the first week.

The 0-1 planning model can be expressed as:

$$\min Q = \sum Q_j\,, j = 1,2, \dots .,402 \tag{22}$$

Solving with MATLAB gives the result, 12 suppliers can meet the above minimum number of suppliers, they are:

$$\text{S131 S143 S201 S229 S275 S282 S329 S340 S352 S356 S361 S395} \tag{23}$$

ISSN: 2688-9323

Before establishing the objective function, first calculate the cost-effectiveness of different types of raw materials, because economy means the most cost-effective situation, compare and discuss the differences between the three types of products, as shown in table 2.

Table 2. Comparison of different types of materials

Product	Price (unit)	1 unit number of products produced	Cost-effectiveness (the price of one unit of product)
A	1.2	0.6	0.72
B	1.1	0.66	0.726
C	1	0.72	0.72

From table 2, it can be seen that Class A raw materials and Class C raw materials are more economical than Class B raw materials, that is, the price of producing the same unit of products is lower, and the objective function is established:

$$\min Z = \sum P_A + \sum P_B + \sum P_C \tag{24}$$

where P represents the amount of raw materials purchased by the enterprise.

There will be a certain loss rate during the transportation of the logistics company. If you want to minimize the loss, you must require the least amount of loss, which can be expressed as:

$$\min K = \sum x_{ij}^t \cdot l_t \cdot p \quad t = 1,2,3 \dots 8 \tag{25}$$

where x_{ij}^t represents the quantity of raw materials shipped by the t-th logistics company to the j-th supplier in the i-th week, l_t represents the loss rate of raw materials transported by the t-th logistics company, and p represents the unit price of different types of raw materials.

The amount of loss is represented by the sum of the product of the quantity of raw materials transported by the logistics company, the loss rate of the logistics company, and the unit price of the materials transported by the logistics company. Among them, l_t is selected by randomly generating the value before the minimum loss rate and the maximum loss rate. By observing the actual loss rate, it can be found that the difference between the minimum and maximum values is not much, so the selection value is reasonable.

Analysis of the above results: Since the weekly supply of each supplier and the weekly loss rate of the forwarder are affected by random factors, the results of each operation will be different, but after multiple simulations, it will show regularity. Random volatility is high.

3. Optimization of Objective Programming Models

The objective function is the procurement cost under the new scheme. In order to simplify the problem, we consider the supply quantity of Class B raw materials to remain unchanged, and only adjust the quantities of Class A and Class C raw materials, which can be expressed as:

$$\min v = \sum new\ U_A + \sum new\ U_C \tag{26}$$

In the formula, new U represents the number of products that can be produced from the new raw materials, and calculates the minimum value of the cost of the objective function.

The constraints are:

$$\sum(p_A + p_B + p_C) \leq \alpha \tag{27}$$

Considering that the quantity of B-type products remains unchanged, and the output of B-type products is not considered in the constraints, it can be expressed as:

$$U_A + U_C = \beta \tag{28}$$

where β represents the minimum value of the sum of products that can be provided by A and B products.

Analysis of the results, we can see that the total amount of A-type materials increased significantly, and C-type materials decreased significantly.

The objective function to maximize profit is:

$$\max q = \sum U \cdot \varphi - \sum p - \sum C_h \tag{29}$$

where U is the number of products that can be produced by the raw materials of the enterprise, φ is the unit price of the unit product, $\sum U \cdot \varphi$ is the total income of the enterprise production, $\sum p$ is the cost of raw materials, and $\sum C_h$ is the storage cost of raw materials. When the production capacity of the enterprise increases, the profit obtained by the corresponding enterprise will also change. If the profit of the enterprise increases while the production capacity increases, the increase in production capacity in this case will no longer be considered.

The first constraint is:

$$U_{stoi} = U_{sto0} \times (1+\eta) - (i-1) \times a(1+\eta) + \sum_i U_i \, , i = 1,2, \dots ,24 \tag{30}$$

where U_{stoi} represents the number of products that can be produced in warehouse storage in week i, U_{sto0} represents the number of products that can be produced in the warehouse at the beginning of the period, until the maximum value of η is found, and a is the number of products that can be produced per week.

The condition corresponding to the weekly supply is that the sum of the weekly supply is less than the sum of the maximum transshipment of 8 forwarders, which is the second constraint:

$$\sum_i \sum_j x_{ij}^t \leq 480000 \tag{31}$$

8 transshipment companies have been identified, so the company receives a maximum of 48,000 cubic meters of material per week, where the sum of the weekly supply from all suppliers is less than the total transshipment volume, for each transshipper, the transshipment volume cannot exceed the maximum transshipment volume:

$$\sum_j x_{ij}^t \leq 6000 \tag{32}$$

The optimal profit value obtained each time is analyzed to obtain the optimal profit value corresponding to the optimal increase η and the supply volume of 50 suppliers and the transshipment volume of the forwarder in the next 24 weeks.

Running through MATLAB results in a weekly production capacity of 2.82×28000 cubic meters.

4. Analysis of the Model

By changing the transportation volume of the logistics company, we can observe the impact on the loss volume. Under the condition that other parameters remain unchanged, we analyze the transshipment volume of the forwarder within a certain range. From small to large, the weekly loss of the company is shown in Fig. 2.

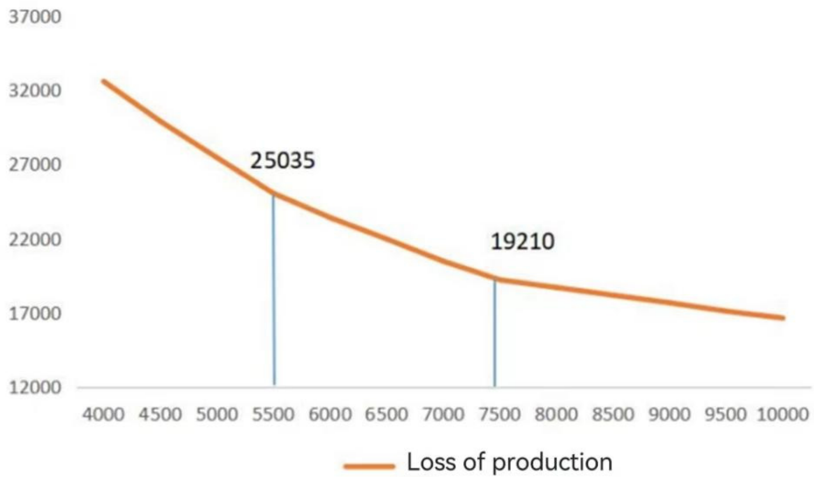

Figure 2. The relationship between wasted output and logistics company's transportation volume

It can be found from Fig. 2 that when the maximum value of transport changes from 4000 to 5500, it has a greater impact on the weekly loss. After 7500, the impact on the weekly loss gradually becomes smaller. Therefore, the maximum transshipment volume of 6000 cubic meters per week is very reasonable.

5. Conclusion

In this paper, we quantitatively analyze and rate the supply characteristics of 402 suppliers by constructing an evaluation model and multiple objective planning models. In addition, the total number of suppliers is used to obtain the minimum value of the objective function, and the production requirements are used as constraints. Lingo software is used to solve the problem, and an integer 0-1 programming model is established. Finally, the most suitable production capacity value was found to be 2.82 *28000 cubic meters, and the ordering and transshipment plan of the enterprise for the next 24 weeks was determined.

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