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Research on the Optimal Scheme of Raw Material Ordering and Transportation in Manufacturing Enterprises

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Abstract: *The ordering and transportation of raw materials in production enterprises is of great significance to ensure the stability and efficiency of the supply chain. Therefore, it is necessary to make a reasonable plan for the procurement and transportation of raw materials. Based on AHP and grey relational analysis, this paper establishes a mathematical model to ensure the importance of enterprise production, and selects the top 50 high-quality suppliers worthy of enterprise cooperation. Then, the linear programming model is used to formulate the most economical ordering scheme and the optimal transshipment scheme (with the least loss)*

Keywords: *Ordering and transportation; AHP analytic hierarchy process; Grey correlation analysis; linear programming model*

1. Introduction

The purchase cost of raw materials directly affects the production efficiency of enterprises. The purchase cost of materials includes two processes: ordering and transportation. Due to the particularity of raw materials, the supplier cannot guarantee to supply goods in strict accordance with the order quantity, and the actual supply quantity may be more or less than the order quantity. In order to ensure the needs of normal production, the enterprise should keep the inventory of raw materials that meet the production needs of two weeks as much as possible. Therefore, the enterprise always purchases all the raw materials provided by the supplier. In the actual transfer process, raw materials will have certain loss (the percentage of loss in supply is called "loss rate"). The ordering uncertainty and transportation loss of raw materials are not conducive to the stability of enterprise supply chain.

In view of this, it is necessary to propose a research scheme to optimize the ordering and transportation of raw materials in production enterprises. The scheme has guiding significance for raw material procurement of relevant enterprises.

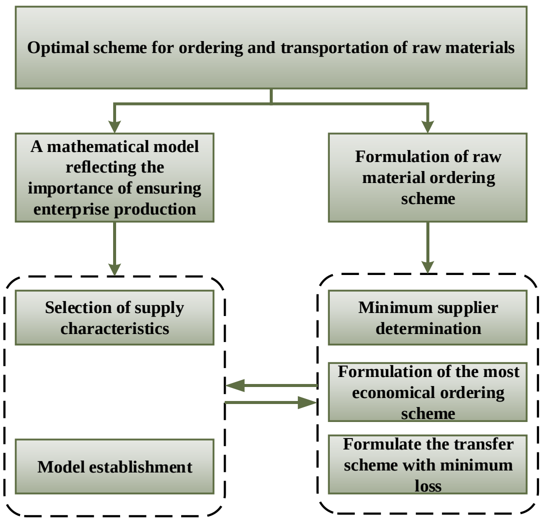

Figure 1: Research path

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2. Model establishment and solution

2.1. Establish a mathematical model reflecting the importance of ensuring enterp-rise production

2.1.1. Selection of supply characteristics

Quantitative analysis based on the supply data of 402 suppliers [1-2]:

$$Z_i = \sum_{1\sim402}^{i} \sum_{1\sim240}^{i} Z_{ij} \tag{1}$$

In formula (1), Z_i represents the total supply volume of the *i*th supplier and Z_{ij} represents the supply volume of the *i*th supplier in week *j*.

F_i indicates that the supplier has met the proportion of the enterprise's order quantity in the first 240 weeks, and Wi indicates the gap between the quantity of goods supplied by the supplier every week and the quantity of goods ordered by the enterprise every week. The calculation formula is [2]:

$$W_i = \frac{\sum_{1\sim402}^{i} \sum_{1\sim240}^{j} |z_{ij} - Q_{ij}|}{z_i} \tag{2}$$

In the announcement (2), W_i represents the supply stability of the *i*th supplier, Z_{ij} represents the supply volume of the *i*th supplier in week *j*, and q_{ij} represents the order volume of the enterprise in week *j* of the *i*th enterprise.

The weights of three supply characteristics obtained by AHP (Table 1).

Table 1: Proportion of importance among three supply characteristics

Supply risk	Supply quantity	Supply stability
1	2	5
1/2	1	4
1/5	1/4	1

Use the data in Table 1 to build the judgment matrix of supply characteristics, and the formula is as follows:

$$h = \begin{bmatrix} 1 & 2 & 5 \\ \frac{1}{2} & 1 & 4 \\ \frac{1}{5} & \frac{1}{4} & 1 \end{bmatrix} \tag{3}$$

After obtaining the judgment matrix, the final weight of each supply feature is calculated by Delphi method, and the results are as follows (Table 2):

Table 2: Final weight of each supply feature

Total supply weight (ZQ)	Supply risk weight (FQ)	Supply stability weight (WQ)
0.261	0.633	0.106

2.1.2. Establish a model to ensure the importance of enterprise production [4]

The weights of the three supply characteristics (Table 1) are brought into the grey correlation analysis method to make it a weighted algorithm [5]:

$$\xi_i(j) = \frac{\min + \rho^* max}{\alpha_{ij} + \rho^* max} \tag{4}$$

$\xi_i(j)$ is the correlation coefficient; a_{ij} represents the jth number of the *i*th supply feature in the two-dimensional list, that is, the self value corresponding to the minimum min and maximum max.

According to the evaluation results, the top 50 high-quality suppliers worthy of enterprise cooperation were selected according to the ranking from high to low (Figure. 2).

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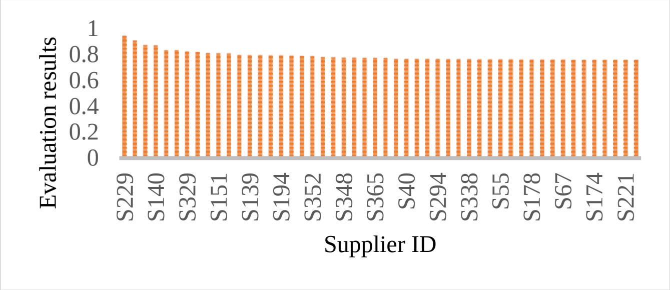

Figure 2: Top 50 suppliers

2.2. Formulation of raw material ordering scheme

2.2.1. Determination of minimum suppliers

Determine the minimum supplier based on the calculation results in 2.1.2. Determine an objective function with the following formula:

$$MIN \sum_{i=1}^{50} V_i Price_i \tag{5}$$

Where X_i represents whether the *i*th supplier is selected or not. Determine unique constraints:

$$X_i n_i \geq 28200 sum\_data \tag{6}$$

Where n_i represents the maximum capacity of the ith supplier.

Create *sum_data* formula is as follows:

$$sum\_data = \frac{\frac{A}{Q_a}+\frac{B}{Q_b}+\frac{C}{Q_c}}{402} \tag{7}$$

The *sum_data* represents the supply-demand ratio between the enterprise and each supplier. Where *A* is the total amount of class a materials supplied in the first 240 weeks, B is the total amount of class B materials supplied in the first 240 weeks, *C* is the total amount of class C materials supplied in the first 240 weeks, Q_A is the total amount of class a materials ordered by the enterprise in the first 240 weeks, Q_B is the total amount of class B materials ordered by the enterprise in the first 240 weeks, and Q_C is the total amount of class C materials ordered by the enterprise in the first 240 weeks.

2.2.2. Formulation of the most economical ordering scheme

The extreme value problem of objective function under linear constraints is studied by using linear programming model:

$$MIN \sum_{i=1}^{18} V_i Price_i \tag{8}$$

Where V_i represents the demand put forward by the enterprise to the *i*th supplier, and $Price_i$ represents the unit volume capacity price of the *i*th supplier.

Based on the objectives of this section, determine the constraints:

$$\sum_{j=1}^{18} (\sum_{i=1}^{18} (XX_{[i][j]} \leq XJ_i) \tag{9}$$

First, the enterprise's demand for each supplier should be less than the supplier's maximum supply in the period. Under this condition, it still needs to ensure that the sum of the actual supply of all suppliers is greater than or equal to the enterprise's capacity demand. According to the calculation results, the most economical ordering scheme formulated by 18 suppliers is selected (Figure. 3).

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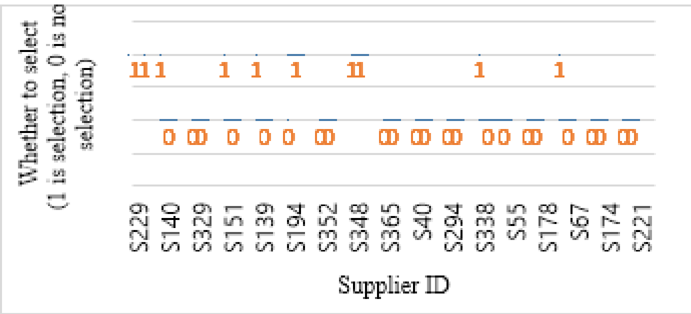

Figure 3: Minimum number of suppliers (18 in total)

2.2.3. Formulate the transfer scheme with minimum loss

According to Figure. 3 and the transportation loss rate data of 8 forwarders [1], the transshipment scheme is formulated. On the premise that the goods of all suppliers can be transshipped, the transshipment volume is within the scope of the forwarder, and each supplier tries to be transshipped by one forwarder. The transshipment scheme with the least loss shall be formulated. Use the linear programming model to solve the extreme value:

$$\sum_{j=1}^{18}(\sum_{i=1}^{18}(XX_{[i][j]} \leq XJ_i) \quad (10)$$

Where $XX_{[i][j]}$ represents the transportation volume of the *j*-th supplier undertaken by the *i*-th forwarder, and $loss_{[i]}$ represents the loss index of the *i*-th forwarder. The following constraints are imposed on the model:

(1) Since the transportation capacity of each forwarder is 6000 m ^{3}/ Week, then it is responsible for the volume of all goods transported. The sum shall be less than or equal to 6000 m ^{3}/ Week, the formula is as follows:

$$\sum_{i=1}^{8}(\sum_{j=1}^{18}(XX_{[i][j]} \leq 6000) \quad (11)$$

(2) In order to ensure that all goods can be transferred, the total quantity of all goods transported by all forwarders shall be greater than or equal to the supply quantity of the supplier. The formula is as follows:

$$\sum_{j=1}^{18}(\sum_{i=1}^{8}(XX_{[i][j]} \leq XJ_i) \quad (12)$$

(3) Since each supplier shall be transshipped by one forwarder as far as possible, the number of forwarders shall not be greater than 6 and shall be as small as possible.

According to the calculation results, four suppliers with the least loss in the transshipment scheme are selected (Table 3).

Table 3: Selected 4 suppliers

Supplier ID	Whether to select (1 is selection, 0 is not selection)
S229	0
S361	0
S282	1
S140	0

3. Promotion and evaluation of the model

The model uses scientific methods such as analytic hierarchy process, gray correlation analysis and linear programming model. The results are run by the program without human intervention. Therefore, the results are reliable and authoritative; Moreover, when dealing with enterprise ordering and transportation problems, the model uses the normalization algorithm to deal with large number of data, which reduces the error of data and improves the reliability.

The disadvantage is that when using the analytic hierarchy process in section 2.1.1, the model selects the importance of the three supply characteristics through human comparison, so it brings subjective considerations into it.

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The model deals with a large amount of data when dealing with enterprise ordering and transportation problems. This model has wide applicability and can be extended to different enterprises.

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