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Research on Multi-objective Optimization of Enterprise Raw Material Ordering and Transshipment Scheme

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Abstract

This paper analyzes the ordering and supply characteristics of suppliers, and gives the best raw material purchase and transfer scheme. In this paper, six indexes are extracted from the order quantity and purchase quantity data, a comprehensive evaluation system is established, and then entropy weight method is used to assign weights to each index. The importance of each supplier is quantified by TOPSIS method. Then, the supply risk degree and production demand were set up, and the optimal decision model was established by using the "0-1" decision variables and taking the minimum sum of decision variables as the objective function. Taking the minimum cost and the inventory meeting the production demand of two weeks as the objective function, a multi-objective optimization model was established to obtain the optimal purchase scheme. The transport optimization model is established with the minimum loss, and the transport scheme and the minimum loss are obtained.

Keywords

Entropy weight method; TOPSIS method; Multi-objective optimization model.

1. INTRODUCTION

With the advent of supply chain management and economic globalization, the competition in the international market is getting hotter and hotter, and the growth and future of enterprises are inseparable from the supply of raw materials, so raw material suppliers are playing an increasingly important role in the development of enterprises' production[1]. In the late 1980s, a brand-new concept of supply chain management was proposed abroad, the essence of which is to integrate the core competencies of each node enterprise[2]. In order to strengthen the management of the supply chain, an enterprise should firstly start from the ordering link of the supply chain, and secondly seize the transportation link in the supply chain management[3], and the enterprise manager can choose the optimal solution between the two, which can make the whole supply chain network develop benignly[4]. In this paper, we need to extract the production characteristics of each supplier, such as average supply quantity, credit, supply capacity, based on the supply quantity data of each supplier, the order quantity data of each supplier and the loss rate data of each forwarder, and construct an evaluation model of the correlation between the order quantity and the supply quantity of the supplier[5], and quantify the supply characteristics of 402 suppliers according to these characteristics. Then, according to the importance analysis of different indicators, the top 50 suppliers will be selected as the supply solution and the suitable forwarder will be found, so as to minimize the economic cost.

2. ESTABLISHMENT OF MODEL

2.1. Supplier Evaluation Model

In order to measure the importance of a supplier, it is necessary to select some characteristic indicators that are relevant to both the supplier and the company as a criterion, and we have established six indicators from the two major directions of the supplier's own strength and supply and demand respectively. After this step is completed, we will determine the weight of each of the six indicators by the entropy weighting method.

The supply quantity reflects the amount of the supplier's supply, the more the supply, the stronger the supplier's supply capacity.

$$T_{S_j} = \sum_{i=1}^{\Omega} S_{ij} \tag{1}$$

The number of suppliers indicates the continuity of the supplier's supply, the more the number of deliveries, the more stable the supply.

$$N_{S_j} = \Omega - \sum_{i=1}^{\Omega} P(S_{ij}) P(x) = \begin{cases} 0 & x = 0 \\ 1 & x \neq 0 \end{cases} j = (1,2,\cdots,402) \tag{2}$$

The ratio between the actual number of deliveries and the number of orders placed by the supplier in these four years reflects the integrity of the supplier, and the producer is more willing to order from a company with high integrity.

$$H_j = \frac{N_{S_j}}{N_{O_j}} \tag{3}$$

The satisfaction rate refers to the ratio of the supplier's supply quantity to the production enterprise's order quantity in these four years.

$$D_j = \frac{T_{S_j}}{T_{O_j}} \tag{4}$$

The degree of non-conformity reflects the average difference between the actual supply quantity of the supplier and the order quantity of the production enterprise, and the larger the degree of non-conformity, the more the actual supply quantity of the supplier deviates from the supply quantity of the enterprise.

$$C_j = \frac{1}{N_{O_j}} \sum_{i=1}^{\Omega} \left(S_{ij} - O_{ij}\right)^2 \Big|_{(S_{ij} - O_{ij}) < A_{S_j}} \tag{5}$$

The matching degree indicates that the supplier can bear the fluctuation of order quantity.

$$C_V = \frac{\sigma}{\mu} \tag{6}$$

where σ denotes the standard deviation and μ denotes the average value.

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Since the price of different types of raw materials and the amount of product produced vary, the type of raw materials that the supplier itself can supply is also an important criterion for a supplier. For each of the three materials A, B, and C, $\lambda a = 0.6\ m^3$, $\lambda b = 0.66\ m^3$, and $\lambda c = 0.72\ m^3$, respectively, for each 1 m^3 of product produced. from the producer's point of view, to produce the most product with the least amount of material, the importance of the three materials A, B, and C to the firm are:

$$\frac{1}{\lambda_1}\frac{1}{\lambda_2}\frac{1}{\lambda_3} \tag{7}$$

The above three values are normalized to give the weights for materials A, B and C as follows:

$$\lambda_a^* \& = \frac{\frac{1}{\lambda_1}}{\sum_{i=1}^{3}\frac{1}{\lambda_i}}\ \lambda_b^* \& = \frac{\frac{1}{\lambda_2}}{\sum_{i=1}^{3}\frac{1}{\lambda_i}}\ \lambda_c^* \& = \frac{\frac{1}{\lambda_3}}{\sum_{i=1}^{3}\frac{1}{\lambda_i}} \tag{8}$$

The entropy weighting method is an objective weighting method, which can eliminate the subjectivity of the weighting to the greatest extent by deriving the appropriate weight for each index based on the characteristics of the index. First of all, we need to normalize the data to ensure the non-negativity of the data.

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

where z_{ij} is the normalized variable, and x_{min} and x_{max} denote the maximum and minimum values of each indicator.

Calculate the weight occupied by the i-th firm under the j-th indicator and consider it as the probability p_{ij} in calculating the information entropy :

$$\frac{1}{p_{ij}} = \frac{1}{z_{ij}}\sum_{i=1}^{n} z_{ij} \tag{10}$$

The information entropy e_j of the j-th supplier supply characteristic index is calculated, and the corresponding information utility value d_j is calculated. The reason for the conversion here is that the larger the information entropy represents, the less information of the supplier characteristic index, and the introduction of the information utility dj can positively measure the amount of information.

$$\begin{gathered} e_j = -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij}\ln\left(p_{ij}\right) \\ d_i = 1 - e_j \end{gathered} \tag{11}$$

The final normalized entropy weight w_j of each supplier characteristic indicator is obtained satisfying the following equation.

$$\frac{1}{w_j} = \frac{1}{d_j}\sum_{j=1}^{m} d_j \tag{12}$$

The final weights of the six indicators were obtained as shown in the table below.

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Table 1. Weight of indicators

indicators	supply quantity	number of suppliers	non-conformity degree	integrity	satisfaction rate	matching degree
weights	0.6952	0.1487	0.0008	0.0366	0.1055	0.0133

The TOPSIS method is a method of ranking samples based on data. The basic idea is to construct an idealized target based on sample data. In this paper, we construct a supplier evaluation model based on the supply characteristics index, and then measure the closeness between the actual supplier and this idealized supplier, and the closer it is, the better the supplier's supply characteristics are.

Find the maximum value of each column, denoted as z_i^+ (i = 1, 2, - - - , Ω), and form a vector.

$$Z^+ = \{z_1^+, z_2^+, \cdots, z_\Omega^+\} \tag{13}$$

This vector represents the ideal supplier. Similarly find the minimum value of each column, denoted as z_i^- (i = 1, 2, - - - , Ω), to form the vector.

$$Z^- = \{z_1^-, z_2^-, \cdots, z_\Omega^-\} \tag{14}$$

This vector represents the least desirable suppliers, each of which has a minimum normalized metric.

The distance between the ith supplier and the target is defined as D_i^+, and the calculation formula is:

$$D_i^+ = \sqrt{\sum_{j=1}^{\Omega} \left(z_j^+ - z_{ij}\right)^2} \tag{15}$$

The distance between the ith supplier and the unsatisfactory target is defined as D_i^-, and the calculation formula is:

$$D_i^- = \sqrt{\sum_{j=1}^{\Omega} \left(z_j^- - z_{ij}\right)^2} \tag{16}$$

The score of the ith supplier is defined as Si, and the calculation formula is:

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{17}$$

Obviously, S_i is between [0, 1]. When S_i is closer to 1, it indicates that the i-th supplier is closer to the ideal target, and the supply capacity of the supplier is higher. On the contrary, the closer S_i is to 0, the farther away the i-th supplier is from the ideal target, and the lower the supply capacity of the supplier is.

2.2. Supplier Evaluation Model

Due to the particularity of materials, the actual supply quantity of suppliers may be larger or smaller than the ordered quantity, which is related to the supply characteristics of each supplier.

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Considering the index of mismatch degree, we decide to revise it and define the supply risk degree of each supplier.

$$C_j = \frac{1}{N_{O_j}} \sum_{i=1}^{\Omega} \frac{(S_{ij}-O_{ij})}{O_{ij}} \Bigg|_{(S_{ij}-O_{ij})<A_{S_j}} \quad (18)$$

Production demand determines the purchase quantity of enterprises, and is positively correlated with the supply output, and is constrained by the market and capacity.

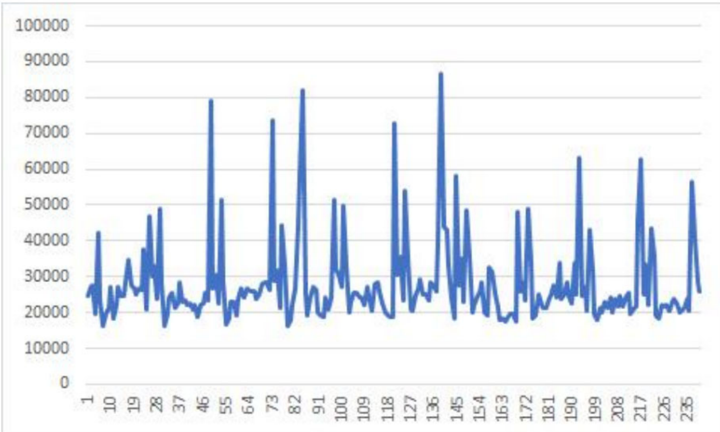

Figure 1. Annual supply output of the manufacturer in the past five years

As can be seen from the supply volumes over the past five years, the demand for production has oscillated with the supply volumes and has been decreasing with each year's peak over time, with less and less fluctuation in the steady phase. We can assume that the producer has reached its production demand every week for the past 5 years, so if the producer reaches its production demand in the next 24 weeks, its future supply production should follow the trend of historical supply production. Therefore, we can take the estimated weekly supply output for the next 24 weeks as the production demand of the producer for the corresponding week.

Considering that the supply output varies with time and the cycle is 48 weeks, and the closer the cycle is, the greater the influence on it, so we make weighted estimation, and set the weights to different values for each year of calculation, as shown in the table below.

Table 2. Annual weight

time	first year	second year	third year	fourth year	fifth year
weights	0.1	0.1	0.2	0.2	0.1

After obtaining the above values, we can establish the supplier number optimization model and set the "0 − 1" decision variable X_j. When $X_j = 1$, it means selecting the j-th supplier. Otherwise, when $X_j = 0$, it means that the j-th supplier is not selected.

The objective function is to minimize the value of the decision variable.

$$\sum_{j=1}^{50} X_j \quad (19)$$

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At the same time, consider whether the total supply output of the selected suppliers in the next 24 weeks meets the production demand, and whether the inventory constraint can be taken into account, introduce the control factor θ = 1.01, and the final model is:

$$\begin{cases} min \sum_{j=1}^{50} X_j \\ \text{s.t.} \dfrac{\sum_{k=1}^{24}\left(\dfrac{\sum_{j_A}\left(s_{k_j}\cdot\varphi_j\cdot X_j\right)}{\Sigma}+\dfrac{\sum_{j_B}\left(s_{k_j}\cdot\varphi_j\cdot X_j\right)}{0.66}+\dfrac{\sum_{j_C}\left(s_{k_j}\cdot\varphi_j\cdot X_j\right)}{0.72}\right)}{\sum_{k=1}^{24} N_k} \end{cases} \tag{20}$$

We set the price of material C as 10,000 RMB /m^3, then we can get the price of material A and material B as 12,000 RMB /m^3 and 11,000 RMB /m^3 respectively, and set as M_a, M_b and M_c.

So we can define the incoming output of week k is S_{C_k}. The output demand of week k is N_{C_k}. The inventory output of week k is R_k. We assume that the enterprise's production capacity is φ = 28200/m^3.

$$\Delta R_k = \begin{cases} 28200 - S_{C_k} & S_{C_k} > 28200 \\ S_{C_k} - N_{C_k} & N_{C_k} < S_{C_k} < \phi \\ S_{C_k} - N_{C_k} & S_{C_k} < N_{C_k} \end{cases} \tag{21}$$

Then the final planning model is:

$$\begin{cases} min \begin{cases} \sum_{k=1}^{24}\left(\sum_{jA}\left(S_{k_j}\cdot\varphi_j\cdot m_A\cdot X_{k_j}\right)+\sum_{jB}\left(S_{k_j}\cdot\varphi_j\cdot m_B\cdot X_{k_j}\right)+\sum_{jA}\left(S_{k_j}\cdot\varphi_j\cdot m_C\cdot X_{k_j}\right)\right) \\ f\left(\sum_{i=1}^{24}\left(R_k - 2*\Phi\right)\right) f(x) = \begin{cases} 0 & x \geq 0 \\ 1 & x < 0 \end{cases} \end{cases} \\ \text{s.t.} \begin{cases} \alpha P_k \leq \sum_{j_A}\dfrac{S_{k_j}X_{k_j}\varphi_j}{\lambda_1}+\sum_{j_B}\dfrac{S_{k_j}X_{k_j}\varphi_j}{\lambda_2}+\sum_{j_C}\dfrac{S_{k_j}X_{k_j}\varphi_j}{\lambda_3} \leq \beta P_k \\ 2\cdot\Phi\alpha \leq R_k \leq 2\cdot\Phi\beta \\ S_{C_k} \leq 48000 \end{cases} \end{cases} \tag{22}$$

On the basis of the selection scheme, the transport decision model is established, and the decision matrix $W_{5\cdot j_k}^{k}$ is introduced, which is the decision scheme of the K-th day. Its element ω^k is a variable of "0 − 1". If its value is 1, it means that the materials of the selected J_k supplier will be transported by the t-th transporter in the K-th week. The final transport scheme model is:

$$\begin{cases} min\left\{\sum_{k=1}^{24}\left(\sum_{j_k}\left(\sum_{t=1}^{5} S_{kj_k}\cdot\varphi_j\cdot l_t\cdot\omega_{j_k,t}\right)\right)\right\} \\ \text{s.t.} \begin{cases} \sum_{t=1}^{5}\left(\omega_{j_k,t}\right) = 1 \\ \sum_{j_k}\left(S_{k\cdot j_k}\cdot\varphi_j\cdot\omega_{j_k,t}\right) \leq 6000 \end{cases} \end{cases} \tag{23}$$

3. SOLUTION OF MODEL

Through the analysis, we finally obtained the quantified supply capacity of 402 suppliers, and selected the 50 suppliers required in the question according to the ranking. The measurement values of the ranking and supply capacity indicators are shown in the table.

Table 3. The top 50 suppliers with the best supply capacity

rank	suppliers	deliverability	rank	suppliers	deliverability
1	S229	0.01093223	26	S374	0.001843897
2	S140	0.008620427	27	S284	0.001800023
3	S361	0.008600035	28	S365	0.001715978
4	S108	0.006968825	29	S040	0.001708885
5	S282	0.005496650	30	S364	0.001663788
6	S151	0.005191342	31	S037	0.001628727
7	S275	0.005174592	32	S266	0.001622799
8	S329	0.005114009	33	S367	0.001622614
9	S340	0.005054619	34	S123	0.001594777
10	S139	0.004497431	35	S007	0.001592597
11	S131	0.004139926	36	S346	0.0015797
12	S308	0.00410794	37	S055	0.001554832
13	S330	0.004102515	38	S338	0.001520506
14	S356	0.003614832	39	S114	0.001510987
15	S268	0.003603784	40	S150	0.001437471
16	S306	0.003515005	41	S080	0.001419078
17	S352	0.003186306	42	S294	0.001418109
18	S348	0.003141298	43	S291	0.001412145
19	S143	0.003005059	44	S218	0.001390513
20	S194	0.002932225	45	S244	0.001381261
21	S307	0.002722293	46	S126	0.001377913
22	S201	0.002577691	47	S098	0.001345708
23	S395	0.002493022	48	S189	0.001242718
24	S247	0.001980925	49	S076	0.001238012
25	S031	0.001867063	50	S221	0.001225231

According to the established multi-objective acquisition optimization model, we consider to assign weight to each objective function and convert it into a single objective function to solve. There are two objective functions, and their corresponding weights are set as 0.6 and 0.4. The optimal acquisition scheme can be obtained by using the MATLAB programming model, and the acquisition price is calculated to be 430235 yuan. The corresponding inventory changes are shown in the figure below, ensuring that the inventory can meet the production demand for two weeks as much as possible.

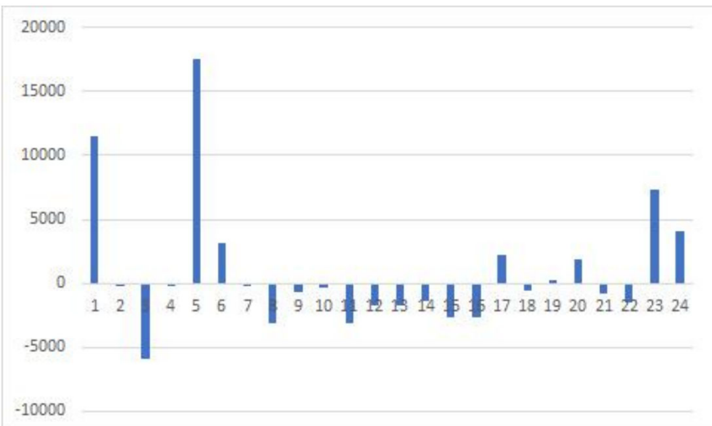

Figure 2. Weekly inventory capacity change chart

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Thus, through the optimization solution of the purchase quantity of A and C, the inventory is greatly reduced, but the number of times that the inventory cannot meet the production demand in the next two weeks also increases correspondingly.

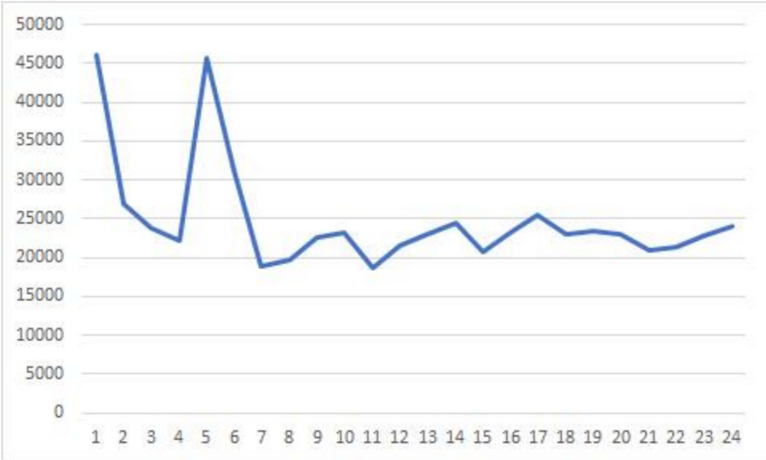

Figure 3. Weekly supply output change chart after decision

The transport optimization model established on the basis of the above results is considered to use Monte Carlo simulation to solve the approximate optimal solution of the model, considering that there are many variables, a total of 24 two-dimensional matrices and independent existence between weeks. Generate the 0-1 matrix that meets the weekly constraint conditions, run 10,000 times, and get the best transfer scheme, and also get the minimum loss rate of 10.0952%.

4. CONCLUSION

This paper quantifies the supply characteristics of suppliers, obtains the importance of suppliers and sorts them, and then establishes an optimal decision model with the minimum sum of decision variables as the objective function. This paper discusses the factors influencing the selection of suppliers. Using entropy weight to reduce the error caused by using subjective knowledge weight; Factors affecting transshipment attrition rates are properly considered.

According to the raw material acquisition optimization model, the purchase price is calculated to be 430235 yuan, which ensures that the inventory can meet the production demand for two weeks. According to the transport optimization model established, it is concluded that the minimum loss rate of 10.0952% can be obtained for the transport scheme of rental price, which meets the production and operation requirements of enterprises and can achieve the minimum economic cost.

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