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Ordering and Transportation Model of Raw Materials in Production Enterprises Based on Integer Programming

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Abstract: *On the issue of ordering and transportation of raw materials in production enterprises, this paper first selects 50 suppliers with high strength score, establishes a 0-1 planning model to make the supplier's supply meet the enterprise's output demand as much as possible, and selects the final 32 suppliers from the 29 suppliers through the total supply and time periodicity. Then, considering the seasonal changes of supply and demand, the order quantity and loss rate of forwarders in the next 24 weeks are predicted through the order quantity and loss rate in the past 5 years, and the optimal order and transfer scheme with the lowest cost is formulated for 32 enterprises by establishing an integer programming model.*

Keywords: *Quantitative analysis, Integer programming, Optimization model, Ordering scheme*

1. Introduction

In recent years, more and more enterprises have realized the importance of supply chain, and the competition between productive enterprises has gradually transformed into the competition between supply chains. Ordering, transportation and storage are not only a part of the supply chain, but also the most consumed elements in the supply chain system. Therefore, the integration and optimization of supplier and forwarder selection and inventory management is of great significance to reduce the operation cost of the whole supply chain.

An existing production enterprise needs to use class A, B and C raw materials. The enterprise arranges production every 48 weeks and needs to formulate raw material ordering and transportation plans in advance. Now we know the enterprise's production capacity and the information required for various raw materials in production, the cost of each raw material, transportation loss rate and so on. It is required to quantitatively evaluate the ordering and transportation scheme of production raw materials and formulate the optimal ordering and transportation plan by integrating the supplier's supply strength, reputation, stability and continuity, its own production capacity, transportation and storage cost and other factors.

Therefore, this problem requires the establishment of a reasonable mathematical model to solve the following problems: first, considering the needs of the enterprise and the characteristics of suppliers, determine that the enterprise should ensure the production needs and select the minimum number of suppliers; Second, predict the demand of the enterprise in the next 24 weeks and formulate the lowest cost ordering scheme; The third is to formulate the transfer scheme with the least loss.

2. Model Establishment and Solution

By analyzing the time series of order quantity and supply quantity, it is not difficult to find that among the suppliers with more contacts with enterprises, some can provide a more stable source of goods every week and have close contact with enterprises. The goods provided by some suppliers have strong time periodicity, which can meet a large number of urgent needs of enterprises at a specific time and season, and generally show a large value in 24 weeks. Therefore, in order to ensure the normal production of enterprises, we must take into account.

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2.1. Establishment and solution of supplier selection model

Through figure 1, it is found that there has been a shortage of supply for many times in the past five years. Therefore, for some important suppliers, the supply volume is corrected by the arithmetic average of their supply volume to measure their formal supply capacity.

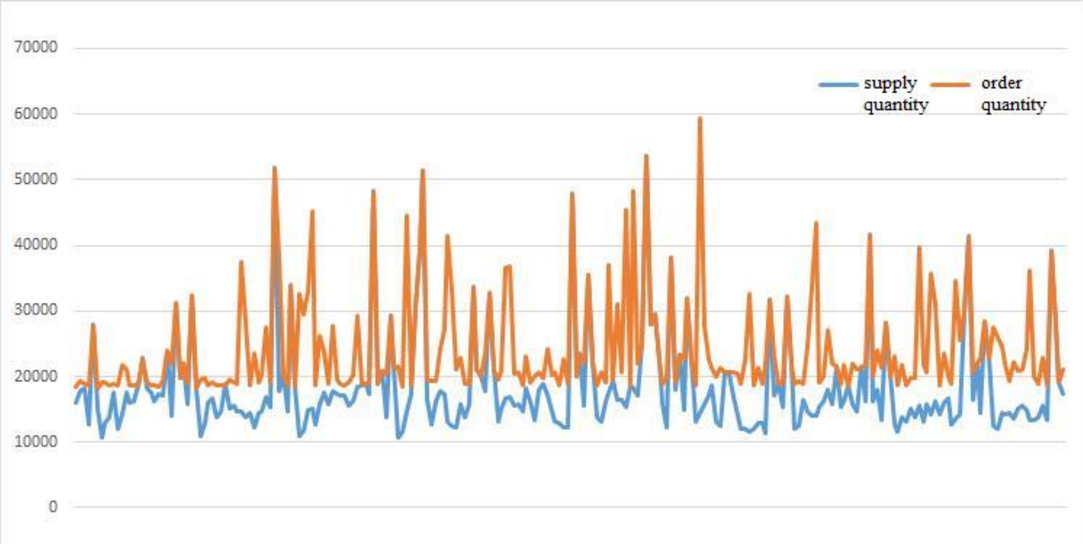

Figure 1: Broken line chart of supply-demand relationship in the past five years

In addition, in view of the problem that it is difficult to determine the demand, combined with the actual situation that the supply is in short supply, we make statistics on the 240 week supply and enterprise order quantity, calculate the ratio and calculate the first coefficient $\xi 1$, which is used to describe the relationship between supply and demand, so as to measure the true situation of suppliers meeting enterprise demand. At the same time, for the shortage of supply, we determine the second coefficient $\xi 2$ through data analysis, and multiply it by the production capacity to obtain the demand of the enterprise. On the other hand, combined with 0-1 planning, the minimum number of suppliers can be obtained.

Before that, we first attribute all raw materials a, B and C in the supply and order quantity to the production quantity based on the following formula, so as to simplify the variables.

$$\begin{gathered}\frac{1}{0.6}\mathrm{S}_{\mathrm{j}\in\mathrm{A}},\quad \frac{1}{0.66}\mathrm{S}_{\mathrm{j}\in B},\quad \frac{1}{0.6}\mathrm{S}_{\mathrm{j}\in C}\\ \frac{1}{0.6}O_{\mathrm{j}\in\mathrm{A}},\quad \frac{1}{0.66}O_{\mathrm{j}\in B},\quad \frac{1}{0.6}O_{\mathrm{j}\in C}\end{gathered} \tag{1}$$

Objective function:

$$\min\ Z=\sum_{j=1}^{50}x_j \tag{2}$$

Where Z is the number of suppliers, x_j is the selection of the 50 most important suppliers. If its value is 1, it means selection, otherwise it is not selected.

Constraints:

The actual supply of the j-th supplier shall be greater than the production capacity multiplied by the floating coefficient

$$\xi_1\overline{O_j}X_j\geqslant 28200\xi_2 \tag{3}$$

Where $\xi 1$=0.9, $\xi 2$=0.86.

To sum up, the 0-1 integer model of the problem is

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$$\min\ Z=\sum_{j=1}^{50}x_j$$
$$s.t.\begin{cases}\xi_1\overline{O_j}X_j\geqslant 28200\xi_2, & j=1,2,...,50\\ x_j=1\text{或}0, & j=1,2,...,50\end{cases} \tag{4}$$

Using MATLAB to solve the above mathematical model, it is obtained that the minimum number of suppliers required is 29. However, through the observation of the enterprise's average 240 week order quantity of these 29 suppliers, as shown in the following figure:

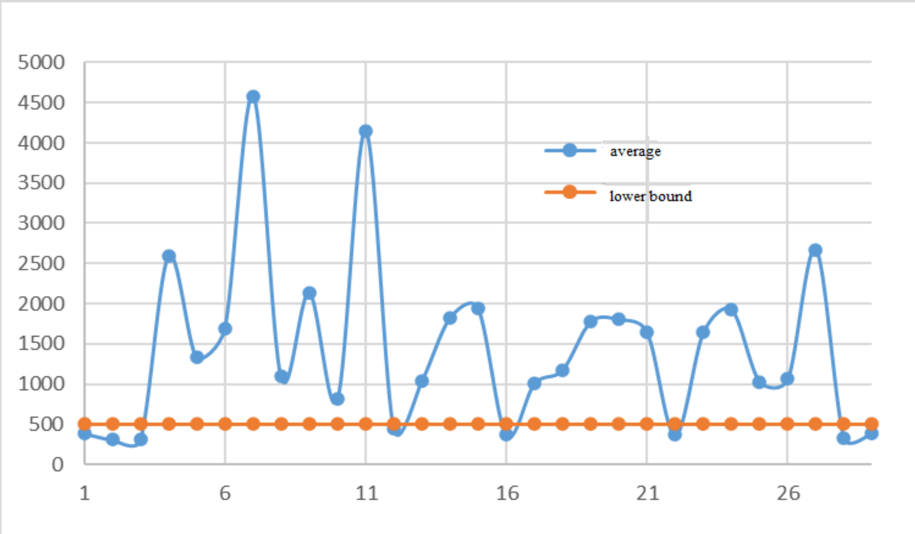

Figure 2: Scatter diagram of mean statistics

We eliminated 8 suppliers with an average value of less than 500, and selected the remaining suppliers from 50 suppliers to meet the production needs of the enterprise. In this way, we finally selected 32 suppliers to meet the production needs of the enterprise.

2.2. Develop the lowest cost ordering scheme

First, we attribute all raw materials A, B and C in the supply and order quantity to the production quantity based on the following formula:

$$\frac{1.2}{0.6}S_{ij\in A},\quad \frac{1.1}{0.66}S_{ij\in B},\quad \frac{1}{0.72}S_{ij\in C}$$
$$\frac{1.2}{0.6}O_{ij\in A},\quad \frac{1.1}{0.66}O_{ij\in B},\quad \frac{1}{0.72}O_{ij\in C} \tag{5}$$

Since both the enterprise's order quantity and the supplier's supply quantity show seasonal changes, and a considerable part of them show semi annual supply and demand, we accumulate the data of the past 5 years by week and divide it into 24 weeks as a cycle. The accumulated value of the enterprise's order quantity in week i of the j cycle is recorded as w_{ij}, We sum and average the order quantity of the corresponding number of the corresponding period, so that we can get the order quantity P_{ij} of the enterprise to j supplier in week i in the next 24 weeks. The formula is as follows:

$$P_{ij}=\sum_{i=1}^{24}\sum_{j=1}^{10}w_{ij} \tag{6}$$

Objective function:

$$\min\ Z=\sum_{i=1}^{24}\sum_{j=1}^{32}y_{ij} \tag{7}$$

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Where Z is the ordering cost and y_{ij} is the ordering quantity of the enterprise to j suppliers in week i.

Constraints:

(1) In 24 weeks, the enterprise's order quantity to j suppliers should be more than the production capacity multiplied by the floating coefficient ξ_3

$$\sum_{i=1}^{24} y_{ij} \geqslant 28200\xi_3 \tag{8}$$

Where ξ_3 =0.8

(2) The order quantity of the enterprise to supplier j in week i shall be greater than the predicted order quantity P_{ij} of the enterprise to supplier j in week i multiplied by the floating coefficient ξ_3

$$y_{ij} \geqslant \xi_3 P_{ij} \tag{9}$$

To sum up, the integer programming model of the problem is

$$\min\ Z = \sum_{i=1}^{24}\sum_{j=1}^{32} y_{ij}$$

$$s.t.\begin{cases} \sum_{i=1}^{24} y_{ij} \geqslant 28200\xi_3,\quad j=1,2,...,32 \\ y_{ij} \geqslant \xi_3 P_{ij},,\quad i=1,2,...,24, j=1,2,...,32 \\ y_{ij} \in Z^+ \end{cases} \tag{10}$$

2.3. Formulate the transfer scheme with minimum loss

In the case of a given supplier, the optimal transfer scheme for the next 24 weeks is given with the goal of minimizing the loss rate of transfer. We predict the loss rate W_i^T of 8 forwarders in the next 24 weeks, and solve the problem based on the integer programming model. In the process of solving, we convert the problem into solving the maximum acceptance per week, that is, we cycle the following model 24 times, as follows:

Objective function:

$$\max\ Z = \sum_{T=1}^{8}\sum_{j=1}^{402} z_{ij}^T\ (1 - W_i^T),\quad i=1,2,...,24 \tag{11}$$

Where Z is the actual quantity accepted by the enterprise, z_{ij}^T is the quantity transferred by the supplier j by the T transporter in week i, and W_i^T is the loss rate of T transporter in week i.

Constraints:

(1)

$$\sum_{j=1}^{402} z_{jT} \leqslant 6000 \tag{12}$$

(2) The total amount of goods transferred by supplier j and 8 forwarders shall be equal to the predicted total amount of orders from the designated enterprise to supplier j in week i.

$$\sum_{T=1}^{8} z_{jT} = P_{ij} \tag{13}$$

To sum up, the integer programming model of the problem is

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$$\max Z=\sum_{T=1}^{8}\sum_{j=1}^{402} z_{ij}^{T}\left(1-W_{i}^{T}\right), \quad i=1,2,...,24$$
$$s.t.\begin{cases}\sum_{j=1}^{402} z_{jT}\leqslant 6000, \quad i=1,2,...,24, T=1,2,...,8\\ \sum_{T=1}^{8} z_{jT}=P_{ij}, \quad i=1,2,...,24, j=1,2,...,402\end{cases} \tag{14}$$

3. Model Evaluation

When predicting the order and supply volume in the next 24 weeks, due to the complexity of the time series, the operation of calculating the mean value of the cycle is simply adopted. Although it can meet the needs of stability and short-term supply capacity, the treatment of some outliers is not very in place. Further improvement can be considered in the subsequent processing of time series, such as screening suppliers with obvious time series and using ARIMA or ARMA models for prediction. Dynamic weighting can also be introduced into some indicators that need to be weighted to make the data difference more objective and significant.

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