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Research on Optimal Ordering and Forwarding Scheme based on Topsis Evaluation Model and 0-1 Planning Model

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Abstract

The ordering and transportation of raw materials for a manufacturing company is a comprehensive task that requires a combination of factors to develop a suitable solution to meet the production needs of the company. In this paper, we evaluate suppliers through Topsis method, predict supplier supply and forwarder loss rate in the next 24 weeks based on time series analysis, and finally develop the best ordering and forwarding plan through 0-1 planning. This paper quantitatively analyzes the supply characteristics of 402 suppliers through the data given in a company and related literature, and four supplier evaluation criteria were finally selected and the scores were calculated by the Topsis method, ranking the top 50 suppliers that is. On this basis, the Winter additive model was used to conduct a time series analysis of the obtained supply quantities of the 50 suppliers in the last five years and the transportation loss rates of the eight forwarders in the last five years to predict the supply quantities of each supplier and the transportation loss rates of the forwarders in the next 24 weeks. The problem is then solved by 0-1 planning to determine the most economical ordering and forwarding solution.

Keywords

Time Series Analysis; Linear Programming; Topsis Method; Entropy Weight Method; 0-1 Planning.

1. Introduction

A company manufactures plates from three types of raw materials, A, B and C. It is known that the weekly production capacity of the company is 28,200 cubic meters and each cubic meter of sheet consumes 0.6 cubic meters of raw material type A or 0.66 cubic meters of raw material type B or 0.72 cubic meters of raw material type C. The enterprise schedules 48 weeks of production per year and needs to make 24 weeks of raw material ordering plan and forwarding plan in advance, i.e. [1]. Determine the raw material suppliers and raw material ordering quantity (order quantity) according to the production capacity, determine the forwarder who will transport the raw material and entrust it to transfer the raw material quantity (supply quantity) supplied by the supplier to the warehouse of the enterprise every week. Due to the special nature of raw materials, the supplier cannot guarantee that the supply quantity is equal to the order quantity, and the actual supply quantity may be more or less than the order quantity required by the enterprise. The company needs to ensure that the warehouse has as much stock as possible to maintain not less than two weeks of production, and at the same time, regardless of whether the actual supply volume of the supplier is more or less than the amount ordered by the enterprise, the enterprise will acquire all. During the transfer process, there is a certain degree of loss of raw materials [2]. We know that there are 8 forwarders, and each of them has a transportation capacity of 6000 m3/week. We set that, in general, the raw materials supplied by one supplier per week are transported by one forwarder as much as possible. A mathematical model reflecting the importance of securing the company's production is

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developed, based on which the 50 most important suppliers are identified among 402 suppliers. On this basis, solve for the minimum number of suppliers to meet the production demand; among these suppliers develop the most economical weekly ordering scheme for the enterprise for the next 24 weeks, and accordingly develop the forwarding scheme with the least losses and analyze the effect.

2. Assumptions and Notations

2.1. Assumptions

We use the following assumptions.

1. Enterprises and other willing to buy all kinds of raw materials.

2. In order to meet the production demand, it is assumed that the total amount of supply is an important indicator for the enterprise to evaluate suppliers.

3. Assume that during transportation, the loss of equal amounts of different materials costs the same amount of money.

2.2. Notations

The primary notations used in this paper are listed as Table 1.

Table 1. Notations

Symbols	Description
$sum\ supply_{ij}$	Total quantity supplied by the i-th forwarder for j weeks
$supply_{ij}$	Supply quantity of the i-th supplier in the j-th week
$order_{ij}$	The order quantity of the enterprise to the i-th supplier in the j-th week
d_i	The difference between the supply quantity and order quantity of the i-th supplier
c_i	Trust level of the i-th supplier
sta_i	Stability of the i-th supplier
s_i	Capacity of the i-th supplier
m_i	Costs used to purchase raw materials from the ith supplier
y_{ij}	Quantity of raw materials transferred by the i-th forwarder for the j-th supplier

3. Model Building and Solving

3.1. Evaluation Model Building and Solving

3.1.1. Selection of Evaluation Indicators

Indicator 1: The total volume of goods supplied by the supplier in the last five years

By comparing the order quantity and supplier supply, we can find that most of the time, most of the suppliers cannot meet the enterprise's ordering needs, the supplier supply is generally low. In order to better meet the production needs of enterprises, the need for suppliers to supply as much as possible. Therefore, we choose the total amount of supply as the first indicator to evaluate the supplier. The first i supplier's total supply is set as.

$$sum_{\sup ply_i} = \sum_{j=1}^{240} \sup ply_{ij} \tag{1}$$

Indicator 2: Supply capacity

For companies with large orders, the more they can meet the needs of the company's order volume, the better the supplier, that is, the stronger the supply capacity of the supplier the better. In this paper, we define the supplier's ability to use the difference between supply and demand, the larger the difference between supply and demand, the stronger the supplier's ability to supply. The difference between supply and demand of the first i supplier is set as.

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$$d_i = \sum_{i=1}^{240} \text{supply}_{ij} - \text{order}_{ij} \tag{2}$$

Indicator 3: Credibility of suppliers

By comparing the order quantity and supplier supply quantity, Suppliers sometimes fail to deliver. Therefore, the ratio between the number of times the supplier delivers on time and the number of times the company orders is defined as a creditworthiness measure and the larger the quantitative value, the higher the credibility of the supplier. The trustworthiness of the i-th supplier is set as [3].

$$c_i = \frac{\text{sum (Supply times)}}{\text{s(Order times)}} \tag{3}$$

Indicator 4: Stability of supply

In indicator 2, we define the definition of supply capacity, to a certain extent to ensure that the supplier's supply can meet the needs of the enterprise, but not enough to ensure that the supplier's supply quantity is greater than the order quantity, so here we define an indicator of stability of supply, which is expressed as the ratio of the number of times the difference between supply and demand is greater than 0 to the number of times the supplier supplies. The stability of the ith supplier is set as.

$$s_i = \frac{sum(\text{ The number of times the supply-demand differential is greater than 0})}{sum(\text{ Number of supplier deliverie times })} \tag{4}$$

3.1.2. Topsis Model Building

Since the importance of each evaluation index is different, different weights need to be assigned to them, and in this question we use the entropy weighting method to determine the weights of the four evaluation indexes [4], to ensure the objectivity and fairness of our conclusion. After assigning the weights, we use the Topsis method to rate the suppliers and get the top 50 suppliers [5].

The weights obtained using the entropy weighting method are shown in Table 2 below.

Table 2. The weights obtained using the entropy weighting method

Total supply quantity	Supply capacity	Supplier Credibility	Stability of supply
0.0425	0.0299	0.9184	0.0092

The top 50 suppliers in the final score ranking is S229, S361, S140, S108, S151, S340, S282, S275, S329, S139, S308, S330, S131, S356, S268, S306, S194, S348, S352, S143, S395, S307, S201, S374, S7, S247, S365, S284, S3, S364, S367, S338, S126, S346, S5, S375, S381, S379, S368, S369, S383, S37, S294, S154, S393, S394, S390, S153, S342, S273.

3.2. Linear Programming Model Building and Solving

3.2.1. Supplier Forecasting Stage

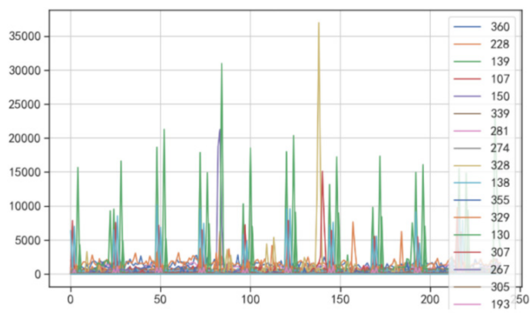

Figure 1. Timing data

Using the pandas library in python, a time-series plot of the 24 weeks of 50 suppliers is shown in Figure 1.

From the image visualization, the time series is smooth and has some periodicity. In order to ensure the significance of the analyzed time series, a white noise test is performed. After that, the stability of each supplier's time series was determined by using the unit root test and KPSS test respectively. The stability of the time series was found to be stable for most of the suppliers. To further analyze the periodicity of the time series, the obtained time series were subjected to additive decomposition, and some results were obtained as shown in Figure 2.

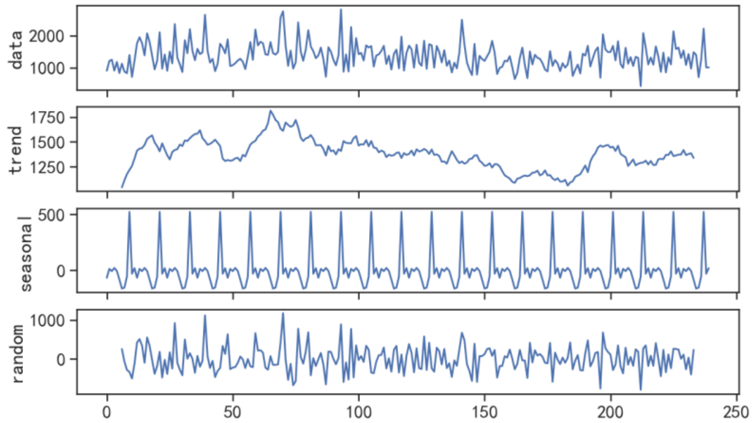

Figure 2. 360 additive model decomposition results

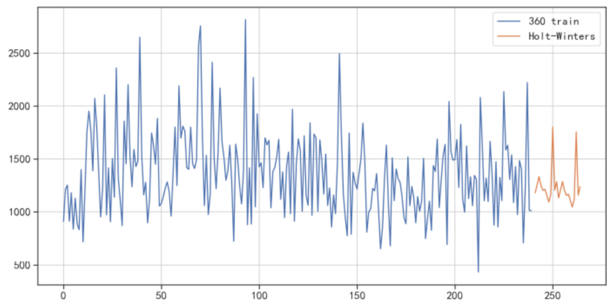

Figure 3. Holt-winters seasonal forecasting model

The seasonal plot shows that almost all time series have a very clear periodicity. And for other trends are relatively smooth. So, it was decided to use Winter's additive model to forecast the supplier's time series, and some of the results are shown in Figure 3 above.

3.2.2. Forwarder Forecast Phase

Using the pandas library in python, a time-series plot of 24 weeks for the eight forwarders is shown in Figure 4.

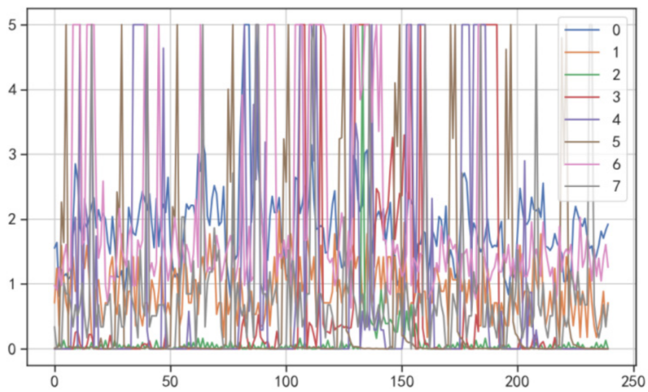

Figure 4. Timing data

From the visualization of the images, the time series is smooth and has a certain periodicity.

In order to ensure the significance of the analyzed time series, white noise test and smoothness test were performed. It was found that all the eight forwarders could perform the additive decomposition of the obtained time series by both tests, and some results were obtained as shown in Figure 5.

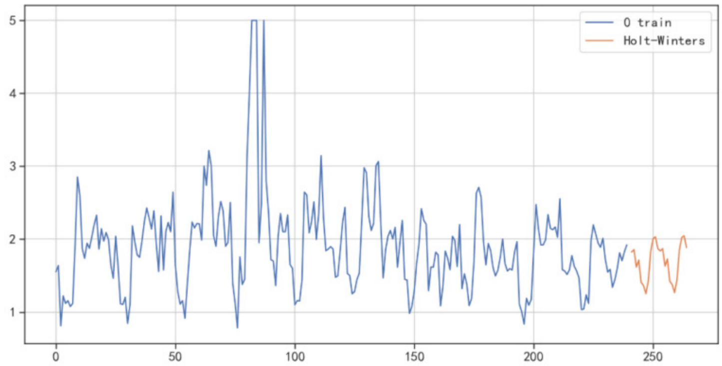

Figure 5. Holt-winters seasonal forecasting model

3.2.3. Supplier Decision Stage

Set up a 0-1 planning model, and set whether to choose the ith supplier as x_i, $x_i = 0, 1$ when $x_i = 0$, represents no choice of the ith supplier, when $x_i = 1$, represents the choice of the ith supplier.

m_i is the price of the corresponding material, s_i is the predicted production capacity.

Where capacity is calculated as the quantity of raw materials divided by the quantity of raw materials required per unit of product.

The objective function is the lowest cost, i.e.

$$\min x_i s_i m_i \tag{5}$$

The constraint is that the total capacity needs to be greater than 28.2 million.

$$\sum_{i=1}^{50} x_i s_i \geq 28200 \tag{6}$$

The linear program is solved using matlab, and the final result is obtained.

3.2.4. Forwarder Decisions Stage

For forwarders, it is important to note that.

Each forwarder has a transportation capacity of 6000 m3/week.

The weekly supply of raw materials from one supplier is transported by one forwarder as much as possible.

Set up a linear programming model with variables, and let the quantity of raw materials to be transported by the ith forwarder for the jth supplier be y_{ij}, where i=1,2,3, ---,8 j=1,2,3,---,50.

The final objective function is the minimum loss, which is converted into the minimum capacity value resulting from the transfer of raw materials, with the following objective function.

$$\min = \sum_{i=1}^{8} \sum_{j=1}^{50} \eta_i y_{ij} \tag{7}$$

Based on a transportation capacity of 6000 m3/week per forwarder, the following inequality constraint is available.

$$\sum_{j=1}^{50} y_{ij} \leq 6000, i = 1, 2, 3, \cdots, 8 \tag{8}$$

In order to ensure that the forwarder is able to transit all deliveries, the following equation constraint needs to be established.

$$\sum_{j=1}^{8}\sum_{i=1}^{50}\frac{y_{ij}}{\omega_j} = \text{fval} \tag{9}$$

where *fval* is the total production capacity of the material for the ordering scheme obtained in the previous subquestion.

However, considering that this condition is too harsh and may cause difficulties in solving it in practice, the equation constraint is converted to an inequality constraint.

$$28200 \le \sum_{j=1}^{8}\sum_{i=1}^{50}\frac{y_{ij}}{\omega_j} \le fval + 100 \tag{10}$$

For the description "one supplier's weekly supply of raw materials is transported by one forwarder as much as possible", the following equation can be established.

$$\sum_{j=1}^{8}\left(y_{ij} > 0\right) = x_i, i = 1,2,3,\cdots,50 \tag{11}$$

For the first 240 weeks and the forecasted 24 weeks, there are suppliers whose supply volume is much larger than the transshipment limit, so the condition "one supplier's weekly supply of raw materials is shipped by one forwarder as much as possible" needs to be removed when the supplier's supply volume is larger than the transshipment limit.

The results are obtained using the linear programming function in matlab.

3.2.5. Implementation Effect Analysis

At the supplier decision stage, the minimum cost for the next 24 weeks is: 29285.18, and the maximum cost is: 30000.96.

In the forwarder decision stage, the minimum loss for the next 24 weeks is: 66.6064, and the maximum damage is: 340.4265.

4. Conclusion

The model is simple, operable and generalizable, and similar problems of enterprises can be solved by this model. The model used in this paper is less sensitive and more robust. For the enterprise, the supplier supply is more random, even through the forecast cannot develop an accurate plan, but the model used in this paper even if the supplier supply situation appears unexpected changes in the forecast, will not have a great impact on the final decision results, and it has a very strong ability to adapt. However, in order to simplify the problem, some assumptions are made in this paper, such as that the loss A and loss B are the same. This will make the final result lose some accuracy.

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