Based on the multi-objective programming model, this paper explores the purchasing and transshipment schemes of enterprises

Jiangpeng Fang*, Wei Wang

School of Economics and Management, North China Electric Power University, Beijing, China, 102206

*Corresponding author: fjp010509@163.com

Abstract. When an enterprise is producing, the production cost directly affects the overall economic benefit. If the production plan can be made in advance according to historical data, the production benefit of the enterprise can be greatly improved. For this reason, according to the historical data provided by a building and decorative board manufacturer, the TOPSIS method is used to evaluate suppliers, considering the minimum number of suppliers required for enterprise production, and trying to pursue the minimum purchasing cost and the minimum transportation loss, a multi-objective mathematical programming model is established, which is solved by sequential algorithm and target weighting method respectively, and the minimum number of suppliers, the ordering scheme and transportation scheme in the next 24 weeks are obtained.

Keywords: Economic efficiency, TOPSIS, Multi-objective planning, Sequential algorithm.

1. Introduction

When enterprises are engaged in production, production costs directly affect the overall economic benefits, and it is particularly important to formulate reasonable ordering and transshipment programs based on historical data to improve enterprise efficiency. Among them, the production cost is composed of procurement costs and transportation inventory costs, which need to consider different factors, such as the production plan of the enterprise, the supply situation of the supplier, etc. This problem requires the establishment of relevant evaluation models[1] and the solution of planning problems, and finally the optimal ordering scheme.

According to the order and supply information of 402 suppliers per week in 5 years and the loss rate of 8 forwarders in 5 years, this paper quantitatively analyzes the relevant data of 402 suppliers, and selects the better suppliers by establishing relevant models under the premise of ensuring the importance of production. With economy as the goal, combined with the relevant conditions to solve the problem of at least how many suppliers to be selected to meet the production, and for these suppliers to develop a 24-week procurement plan, put forward the least loss of the transfer plan, analysis the final result .

2. Mathematical models

2.1 Based on entropy rights method TOPSIS evaluation model

2.1.1 Establishment of indicators:

By consulting a large number of literatures[2] on supplier selection and analyzing the attachment data, we define the two indicators for evaluating the importance of suppliers in this problem as the average deviation rate e_i and the average supply share s_i. The calculation formulas of the two indicators are as follows.

The average deviation rate of the (i =1,2,…,402) supplier is e_i use d_{ij} to represent the deviation rate of the i supplier in the j week, use the 0-1 variable x_{ij} to calculate the number of weeks with orders, and o_i represents the order quantity of the enterprise to the i supplier in the j week:

$$d_{ij}=\begin{cases}\dfrac{|o_{ij}-p_{ij}|}{o_{ij}},o_{ij}\neq 0;\\ 0\qquad\qquad ,o_{ij}=0;\end{cases} \tag{1}$$

$$x_{ij}=\begin{cases}0,\ o_{ij}=0;\\ 1,\ o_{ij}\neq 0;\end{cases} \tag{2}$$

$$e_i=\frac{\sum_{j=1}^{m}d_{ij}}{\sum_{j=1}^{m}x_{ij}} \tag{3}$$

Average supply share s_i, where indicates the shipment quantity of supplier i in week j:

$$s_i=\frac{\sum_{j=1}^{m}s_{ij}^{'}}{240} \tag{4}$$

2.1.2 Unified indicator type:

Wherein the average deviation rate is a very small index, the average supply share is a very large index, and the two indexes are unified and positively processed to be converted into the very large index to obtain a standardized decision matrix, wherein the very small index is converted into the very large index as follows:

$$\max(e_i)-e_i \tag{5}$$

The initial matrix A (a_{ij}), i.e. A (e_i, s_i), is obtained after the two evaluation indexes (average deviation rate and average supply share) of 402 evaluation objects (suppliers) are normalized.

In order to eliminate the dimensional influence of different indexes, the standardization formula (6) is used to standardize the indexes, and the standardization matrix B (B_{ij}) is obtained:

$$B(b_{ij})=\frac{a_{ij}}{\sqrt{a_{1j}^2+a_{2j}^2+\cdots+a_{nj}^2}} \tag{6}$$

Calculate the information entropy C_j of each index:

$$c_j=-\frac{\sum_{i=1}^{n}b_{ij}\ln b_{ij}}{\ln 2},\ j=1,2 \tag{7}$$

Calculation of information utility value:

$$d_j=1-c_j \tag{8}$$

The entropy weight is obtained by normalization:

$$w_j=\frac{d_j}{\sum d_j} \tag{9}$$

Define the maximum value:

$$C^+=(C_1^+,C_2^+)=(\max\{c_{11},c_{21},\cdots,c_{n1}\},\max\{c_{12},c_{22},\cdots,c_{n2}\}) \tag{10}$$

Define the minimum value:

$$C^-=(C_1^-,C_2^-)=(\min\{c_{11},c_{21},\cdots,c_{n1}\},\min\{c_{12},c_{22},\cdots,c_{n2}\}) \tag{11}$$

Define the distance between the i_{th} evaluation object and the maximum value:

$$D_i^+=\sqrt{(C_1^+-c_{i1})^2+(C_2^+-c_{i2})^2} \tag{12}$$

Similarly, the distance between the i evaluation object and the minimum value can be defined;
Score calculation of the i_{th} supplier:

$$E_i=\frac{D_i^-}{(D_i^-+D_i^+)} \tag{13}$$

By calculating and ranking them, the required results can be obtained.

2.2 Multi-objective mathematical programming model

2.2.1 Selection of decision variables:

$$x_i = \begin{cases} 0, & not\ select\ the\ i_{th}\ supplier; \\ 1, & select\ the\ i_{th}\ supplier; \end{cases} \tag{14}$$

$$y_{ij} \geqslant 0,\ required\ capacity\ of\ the\ i_{th}\ supplier\ in\ week\ j; \tag{15}$$

$$z_{ijk} \geqslant 0,\ capacity\ of\ the\ i_{th}\ supplier\ transferred\ by\ the\ k_{th}\ forwarder\ in\ week\ j; \tag{16}$$

2.2.2 Establishment of objective function:

Enterprises in the premise of meeting the production needs as few as possible to choose as few suppliers as possible, we establish the objective function one:

$$\min \sum_{i=1}^{n} x_i; \tag{17}$$

The second problem requires the enterprise to select as few suppliers as possible on the premise of meeting the production demand. We establish the first objective function:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{m} y_{ij} p_i,\ p_i = \begin{cases} 0.72, & materials\ A, C; \\ 0.726, & material\ B; \end{cases} \tag{18}$$

According to the minimum loss transshipment scheme required by the subject, considering that the supplier in the subject cannot supply goods strictly according to the order quantity, and the actual supply may be greater or less than the order quantity, σ_i is introduced to represent the actual delivery rate of the i_{th} supplier, which is used to simulate the actual supply situation after fluctuating according to the order quantity. λ_k is the average loss rate of each forwarder, and the objective function III is established as follows:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{l} z_{ijk} \lambda_k; \tag{19}$$

2.2.3 Determination of constraint conditions:

Considering the condition that the supplier is selected only when the i_{th} supplier has an order quantity (x_i=0) and is not selected without an order quantity (x_i=0), the following constraints are established, where M is a very large number:

$$Mx_i \geqslant \sum_{j=1}^{m} y_{ij},\ i = 1, 2, \cdots, n; \tag{20}$$

$$x_i \leqslant \sum_{j=1}^{m} y_{ij},\ i = 1, 2, \cdots, n; \tag{21}$$

According to the production requirements of the enterprise, the raw material inventory should not be less than the production demand for two weeks, and the following constraints are obtained, R_j represents the remaining inventory of the enterprise in the j_{th} week, and C is the capacity consumed by the enterprise per week, that is, 28,200 m^3:

When the supplier's supply quantity is more or less, the enterprise always purchases all of them, and the raw materials actually delivered by the supplier are transferred by the forwarder, which is

$$R_j \geqslant 2C;\ j = 1, 2, \cdots, m; \tag{22}$$

$$R_j = \begin{cases} 2C & , j = 0; \\ R_{j-1} + \sum_{i=1}^{n} \sum_{k=1}^{l} z_{ijk}(1 - \lambda_k) - C, & j \geqslant 1; \end{cases} \tag{23}$$

subject to the following constraints:

$$\sum_{k=1}^{l} z_{ijk} = y_{ij}\sigma_i,\ i=1,2,\cdots,n;\ j=1,2,\cdots,m; \tag{24}$$

In consideration of satisfying the order quantity of the enterprise as much as possible, and the supply capacity of the supplier is limited in the actual situation, we consider that the supply capacity of the supplier is higher than the historical weekly average capacity S_{avg}, and obtain the following constraint conditions. The maximum supply quantity factor μ (μ > 1) is introduced to indicate that the supply is a multiple of the maximum capacity:

$$y_{ij} \leqslant \mu s_{avg},\ i=1,2,\cdots,n;\ j=1,2,\cdots,m; \tag{25}$$

In addition, an important constraint is that the maximum transshipment volume of each forwarder is 6000/week, and the transshipment capacity of each forwarder is converted into the actual volume of transshipment according to the type of raw materials (ξ_i is the conversion rule), and the following constraints are obtained:

$$\sum_{i=1}^{n} z_{ijk}\xi_i \leqslant 6000,\ k=1,2,\cdots l; \tag{26}$$

$$\xi_i = \begin{cases} 0.6, & \textit{the material of the } i_{th} \textit{ supplier is } A; \\ 0.66, & \textit{the material of the } i_{th} \textit{ supplier is } B; \\ 0.72, & \textit{the material of the } i_{th} \textit{ supplier is } C; \end{cases} \tag{27}$$

Through the above constraints, the decision domain of this problem can be established. The selection of forwarders is based on the principle that the raw materials supplied by one supplier every week should be transported by one forwarder as far as possible. However, we do not want to reject some suppliers with large weekly supply, so we limit that each supplier can choose two forwarders at most every week. Therefore, the constraints are established as follows:

$$Mv_{ijk} \geqslant z_{ijk}\ ,\ v_{ijk} \leqslant z_{ijk}; \tag{28}$$

$$\sum_{k=1}^{l} v_{ijk} \leqslant 2; \tag{29}$$

$$v_{ijk} = \begin{cases} 0, & \textit{the } i_{th} \textit{ supplier will not select the } k_{th} \textit{ forwarder in week } j; \\ 1, & \textit{the } i_{th} \textit{ supplier will select the } k_{th} \textit{ forwarder in week } j; \end{cases} \tag{30}$$

2.2.4 Simulation verification model based on Monte Carlo Method

This problem belongs to the multi-objective planning problem, considering the use of sequential algorithm[3-4], the multi-objective planning problem is decomposed into a series of single-objective planning problems, and the three goals of the minimum number of suppliers, the most economical ordering scheme, and the least loss-free transshipment scheme are solved in turn.

First of all, we screen out the order data of the historical order volume greater than 500, and through the statistical analysis of the frequency of its actual shipment rate, we can see that for a definite order, the maximum supply of the supplier is equal to the order quantity. Then the program is written through lingo[5], and two parameter values are substituted, and the minimum number of suppliers obtained is 8.Then, in the procedure for solving target two, the solution result of goal one is substituted as a known parameter to obtain the most economical ordering scheme[6] and the order cost 557005.4.Finally, the minimum number of suppliers obtained by target 1 and the order cost obtained by target 2 are substituted into the objective function 3 solution as known parameters, and the transshipment scheme and transshipment loss cost with the smallest loss are obtained. The results are presented in the form of an appendix.

In order to further verify the rationality of the above ordering and transshipment schemes[7], we have designed a simulation verification model based on Monte Carlo Method. The designed Monte Carlo algorithm pseudocode is as follows Figure 1.

```
Monte Carlo algorithm implementation
    input:
      o_plan:order scheme (in units of volume of raw materials)
      shipment:actual shipment
      z:transshipment protocols
      d:the sum of the absolute value of the actual supply and the dispersion of the
    predetermined transfer scheme
for i=0->n do
    for j=0->m do
        Generates a random number from 0 to 1
        if rand_num<0.11
      shipment(i,j)=o_plan(i,j)*0.2*rand_num/0.11;
    endif
        if 0.11<=rand_num<0.25
      shipment(i,j)=o_plan(i,j)*(0.2*(rand_num-0.11)/0.15+0.8);
    end if
        if 0.25<=rand_num
      shipment(i,j)=o_plan(i,j);
        end if
  end for
end for
for i=0->n do
    for j=0->m do
        d=d+|shipment(i,j)-sum(k:z(i,j,k))|;
    end for
end for
```

Figure 1. Monte Carlo pseudo-code diagram

3. Analysis of results

3.1 Sensitivity analysis of receipt rate

In view of the deviation between the order quantity predicted by the planning model[8] and the historical data, we test the sensitivity of the actual receipt rate σ_i and the maximum supply factor μ , By fixing the maximum supply factor and changing the actual receipt rate, observe the changes of the minimum number of suppliers, order cost and transit loss cost, as shown in Figure 2,3.

As shown in Figure 2, the larger the actual delivery rate is, the smaller the ordering cost and the minimum number of suppliers are required. This is because when the actual delivery rate is larger, the actual situation reflected is that suppliers have sufficient supply capacity to meet the needs of enterprises as much as possible. For enterprises, there is no need to order more goods to ensure production, which further reduces the pressure of inventory and transshipment. On the other hand, when the supplier's supply capacity is large, only a small number of suppliers are needed to meet the production and inventory demand.

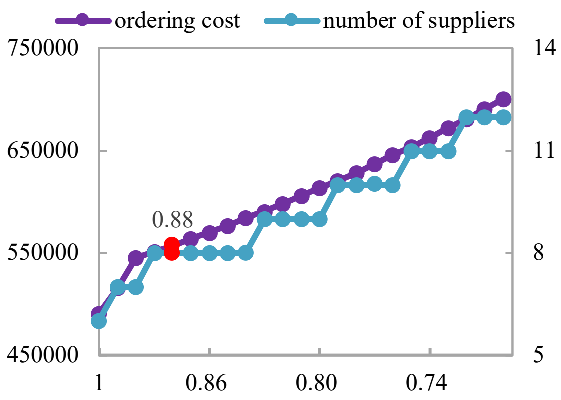

Figure 2 Changes 1 in ordering costs and number of suppliers

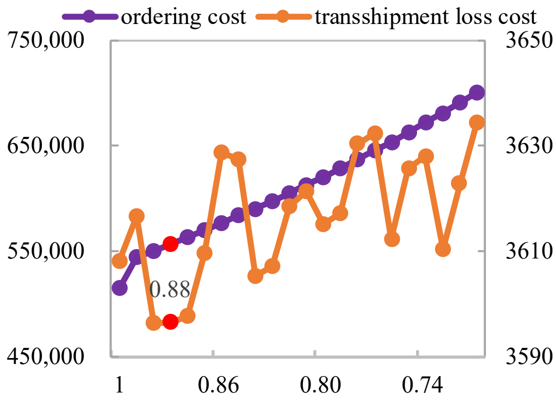

Figure 3 Change 1 in ordering costs and transshipment loss costs

As shown in Figure 2, the larger the actual delivery rate is, the smaller the ordering cost and the minimum number of suppliers required are. This is because when the actual delivery rate is larger, the actual situation reflected is that suppliers have sufficient supply capacity to meet the needs of enterprises as much as possible. For enterprises, there is no need to order more goods to ensure production, which further reduces the pressure of inventory and transshipment. On the other hand, when the supplier's supply capacity is large, only a small number of suppliers are needed to meet the production demand and inventory demand.

As shown in Figure 3, there is no obvious correlation between the loss cost of transshipment and the actual delivery rate, because the loss cost of transshipment depends on two aspects: the transshipment volume and the loss rate of the forwarder. In this problem, the transshipment quantity is only related to the production demand and inventory demand, and has nothing to do with the order quantity. This is because when the production demand and inventory demand are met, it is easier to meet the second objective and minimize the order cost. The loss rate of the forwarder in this question is a fixed historical average loss rate. To change the loss rate, only the choice of the forwarder can be changed. In order to meet the third objective, the forwarder with a lower loss rate is often preferred. Obviously, when the transshipment volume is fixed, the transshipment scheme is also fixed.

3.2 Sensitivity analysis of the maximum availability factor in the model

Similarly, by fixing the actual receipt rate and changing the maximum supply factor, the changes of the minimum number of suppliers, order cost and transit loss cost are obtained as shown in Figure 4 and Figure 5 below.

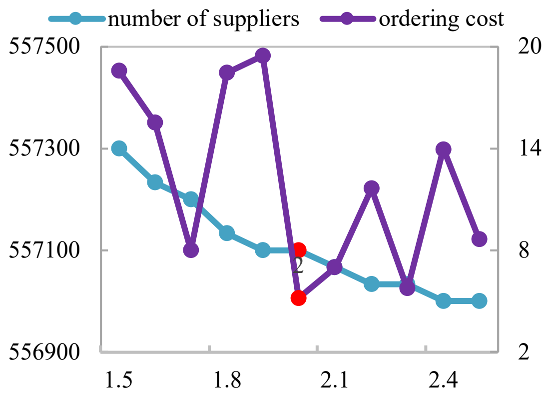

Figure 4 Change in ordering costs versus number of suppliers

Figure 5 Changes in ordering costs and transshipment loss costs

As shown in Figure 4, when the maximum supply factor increases, the number of minimum suppliers required decreases continuously. This is because the maximum supply factor directly reflects the supply capacity of suppliers. Similar to the above analysis, it is not difficult to understand the change in the number of suppliers.

As shown in Figure 5, there is no obvious correlation between the maximum supply factor and the order cost and the transshipment loss cost, because the maximum supply factor only affects the supplier's supply capacity, and has no effect on the order quantity, transshipment quantity, purchase unit price and transshipment loss rate.

To sum up, the ordering cost is related to the actual delivery rate and is more sensitive; the number of suppliers and the maximum supply factor and the actual delivery rate, and they are more sensitive; Transshipment loss cost and the maximum supply factor The actual delivery rate is irrelevant. For enterprise decision-makers, considering a smaller actual delivery rate and a larger maximum supply factor is a way to give up part of the economic benefits and seek a lower risk. How to balance the economic benefits and risks is more difficult, and the result of this problem planning solution only gives a feasible reference scheme[9] with moderate economic benefits and risks.

3.3 Sensitivity analysis of weights in the model

We give different weights to α, β and γ, and the results are shown in Table 1. When the weights change[10], the ordering cost under the most economical ordering scheme, the minimum transshipment loss cost, the absolute value of the deviation between the actual supply quantity generated by Monte Carlo simulation and the transshipment scheme, and the proportion of the absolute value of the deviation to the total transshipment volume do not change much. It is not sensitive to the change of weight, while the minimum number of suppliers is sensitive to the change of weight. The change of α weight is extremely sensitive. When α is large, it shows that the objective of minimum number of suppliers is more important for enterprise decision-making, that is, the value of α is equal to the importance of minimum number of suppliers in the minds of decision-makers.

Table 1 Results under different weights

α	β	γ	g1	g2	g3	Absolute and dispersion	Absolute dispersion and proportion of total transshipment
0.4	0.35	0.25	35	556880.5	4077.922	141478.1	20.8%
0.45	0.35	0.2	26	556469.5	3624.158	141440.1	20.8%
0.5	0.3	0.2	22	556481.2	3614.3	140943.5	20.7%
0.6	0.3	0.1	24	556474.7	3619.737	141551.7	20.8%
0.7	0.2	0.1	19	556495	3603.196	140909.7	20.7%
0.8	0.15	0.05	17	556505.1	3603.454	141081.6	20.7%
0.99	0.008	0.002	9	556564.8	3596.653	140458.8	20.7%

4. Summary

For the production problems of enterprises, more than one factor is often considered. This paper analyzes the actual production cases of enterprises and gives reasonable results. The robustness and practicability of the model are verified by sensitivity analysis, which can be extended to the decision-making of actual production planning.

In the selection of suppliers, we use the entropy method to calculate the weight more objective and more accurate. We use the sequential algorithm and the goal weighting method to solve the problem: in the sequential algorithm, the lingo solution time is 5 to 8 minutes, while the goal weighting method solution time is within 30 seconds, which reduces the solution time by an order of magnitude. By comparing and selecting the results of the two algorithms, it is more conducive for decision makers to formulate the scheme. In the evaluation of the order plan and the transshipment plan, we use the Monte Carlo method, and carry on the frequency statistics to the historical actual delivery rate, and take this as the basis of the Monte Carlo evaluation, in order to simulate the actual situation well, after many times of simulation, we find that the order plan and the transshipment plan are more reasonable, which shows that the model is more stable.

However, due to the large amount of data processed in this paper, the direct observation effect is not obvious, and there is no good visualization scheme. The factors considered are still limited, and there may still be more complex conditions that are not considered comprehensively enough, resulting in some deviation from the actual situation; when using the target weighting method. The selection of the weight is subjective, and when the scheme is selected according to the solution obtained by multiple algorithms, it also has a certain subjectivity. In the future, when promoting specific problems, we can improve and upgrade from these aspects.

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