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Research on Enterprise Order and Transshipment Strategy Based on Factor Analysis and Dynamic Programming

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Abstract: *The research on ordering and transportation strategy optimization of raw materials has a profound impact on the development of enterprises. Based on factor analysis and dynamic programming method, this paper reasonably formulates raw material ordering and transshipment optimization strategy. Due to the uneven quality of each supplier, transporters transport loss rate is not the same. For enterprises, how to formulate the most economical raw material ordering plan and the least loss transshipment plan has become a key issue to be solved. In this paper, a dynamic programming model and a 0-1 programming model are established to solve the problem of enterprise transshipment ordering scheme under different needs.*

Keywords: *Factor analysis, Dynamic programming, Transport loss, Transport strategy*

1. Introduction

In general, in the process of production behavior, enterprises usually need to make raw material ordering and transshipment plan in advance, that is, to determine the ordered raw material suppliers and the corresponding weekly raw material ordering quantity according to the requirements, and to determine the weekly raw material supply transshipment quantity of logistics companies and suppliers [1]. In order to ensure the needs of normal production, enterprises should maintain as much as possible the inventory of raw materials to meet the needs of two weeks of production, so enterprises always purchase all the raw materials actually provided by suppliers [2-3].

In the process of transshipment, the number of raw materials actually transported by the transporter to the warehouse of the enterprise is called ' receiving quantity '. The transportation capacity of each transporter is limited, and the raw materials will be lost. The procurement cost of raw materials affects the production efficiency of the enterprise [4-5]. Therefore, enterprises need to quantitatively analyze the supply characteristics of suppliers when formulating raw material ordering and transshipment plans, and determine several most important suppliers to provide stable raw materials while ensuring that the production schedule of enterprises is not affected [6].

In this regard, this paper takes the number of suppliers, the production cost of raw materials and the transshipment loss as the objective function, and takes the weekly energy production of suppliers, the inventory of enterprises, the transportation capacity of transshipment and the uniqueness of enterprises ' choice of transshipment as constraints to establish dynamic programming models respectively [7]. Hope to minimize the number of suppliers, raw material production costs, transshipment losses, to determine the optimal ordering scheme and transshipment scheme [8].

2. Establishment and Solution of Model

Assuming that the weekly production capacity of the enterprise can be met, the raw materials supplied by the supplier are constrained, and a dynamic optimization model is established to determine the production enterprise in the case of meeting the raw material demand, at least how many suppliers are selected to supply raw materials to meet the production demand. Then, the inventory of the enterprise, the supply of the supplier, the transshipment capacity of the transporter, and the uniqueness of the transporter are constrained, and the loss of goods during transportation is considered. By establishing a multi-objective programming model, based on genetic algorithm, the weekly optimal ordering scheme and transshipment scheme are solved weekly, and finally the optimal ordering scheme and transshipment scheme are obtained.

2.1. Supplier Optimization Model Based on 0-1 Integer Programming

2.1.1. Objective Function

Before establishing the ordering and transshipment plan, we must first determine the selected suppliers. We screen from the two aspects of weekly production capacity and the amount of procurement to meet the appropriate suppliers for the enterprise. Assuming that the decision variables satisfy the 0-1 distribution, z is the minimum number of suppliers to meet the production needs of the enterprise, the goal programming model of the problem is:

$$\min z = \sum_{i=1}^{m} a_i + \sum_{i=1}^{u} b_i + \sum_{i=1}^{t} c_i \tag{1}$$

$$\left(\frac{a_i \sum_{i=1}^{m} X_A}{0.6} + \frac{b_i \sum_{i=1}^{u} X_B}{0.66} + \frac{c_i \sum_{i=1}^{t} X_C}{0.72} \right)(1-\alpha_i) \ge 2.82 \times 10^4 \tag{2}$$

$$\frac{X_{At}}{0.6} + \frac{X_{Bt}}{0.66} + \frac{X_{Ct}}{0.72} \ge 5.64 \times 10^4 \tag{3}$$

$$a_i, b_i, c_i = \begin{cases} 1 & \text{Select the supplier} \\ 0 & \text{Do not select this supplier} \end{cases} \tag{4}$$

$$\alpha_i = \frac{1}{240} \sum_{i=1}^{240} \frac{1}{n_i} \sum_{j=1}^{n} \alpha_{ij} \tag{5}$$

$$\alpha_i = \frac{m-n}{m} \tag{6}$$

Where a_i, b_i, and c_i are logical variables valued as 0 or 1, meaning whether the supplier is involved in the supply. 0 indicates that the supplier is not involved in the supply, 1 indicates that the supplier is involved in the supply. In the objective function represents the number of suppliers participating in weekly supply.

2.1.2. Constraint Condition

(1) Capacity Constraints

In order to achieve the optimal goal, it is assumed that the weekly production capacity of the enterprise is 28,200 cubic meters. Due to the different raw materials supplied by different suppliers, we set X_A as the energy production of raw material A supplied by the supplier, X_B as the energy production of raw material B supplied by the supplier, X_C as the energy production of raw material C supplied by the supplier, a_i, b_i, c_i as whether to supply such raw materials. The loss rate of the supplier in the process of transporting the goods. The loss rate is usually between 0 and 0.05, the value is small. We integrate the historical data given by the attachment and calculate the average loss rate as the estimated value of the loss rate. Finally, the estimated loss rate is 1.28 %.

Therefore, we have the following constraints on production capacity:

$$\alpha_i = \frac{1}{240} \sum_{i=1}^{240} \frac{1}{n_i} \sum_{j=1}^{n} \alpha_{ij} \tag{7}$$

$$\alpha_i = \frac{m-n}{m} (m \text{ is supply, } n \text{ is acceptance}) \tag{8}$$

$$\left(\frac{a_i \sum_{i=1}^{m} X_A}{0.6} + \frac{b_i \sum_{i=1}^{u} X_B}{0.66} + \frac{c_i \sum_{i=1}^{t} X_C}{0.72} \right)(1-\alpha_i) \ge 2.82 \times 10^4 \tag{9}$$

(2) Inventory Constraints

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In order to achieve the optimal goal, considering that the enterprise should maintain as much as possible not less than the raw material inventory to meet the two-week production demand, X_{A1}, X_{B1}, X_{C1} are set to supply suppliers with raw materials A, B, C of the first week of energy production, so we have the following constraints on inventory:

$$\frac{X_{At}}{0.6}+\frac{X_{Bt}}{0.66}+\frac{X_{Ct}}{0.72}\geq 5.64\times 10^4 \tag{10}$$

2.2. Construction of Ordering Scheme Optimization Model

2.2.1. Determination of Constraint Conditions

(1) Capacity Constraints

In order to achieve the optimal goal, considering that the weekly production capacity of the enterprise should reach 28,200 cubic meters, due to the different raw materials supplied by different suppliers, we set X_A as the energy production of raw material A supplied by suppliers, X_B as the energy production of raw material B supplied by suppliers, X_C as the energy production of raw material C supplied by suppliers, a_i, b_i, c_i as whether to supply such raw materials. The loss rate of the supplier in the process of transporting the goods. Therefore, we have the following constraints on production capacity:

$$\left(\frac{a_i\sum_{i=1}^{m}X_A}{0.6}+\frac{b_i\sum_{i=1}^{u}X_B}{0.66}+\frac{c_i\sum_{i=1}^{t}X_C}{0.72}\right)(1-\alpha_i)\geq 2.82\times 10^4 \tag{11}$$

(2) Inventory Constraints

In order to optimize the target, considering the enterprise to keep as much as possible not less than two weeks to meet the production needs of raw material inventory. In this regard, we update the inventory constraints. For manufacturing enterprises, the role of warehouse inventory is to prevent the occurrence of unexpected situations and make the production of raw materials is not enough, so that the production volume is inconsistent with expectations. Therefore, the raw materials required to maintain two weeks of production is the lower limit of warehouse raw material inventory. In this regard, we need the stock of week t to meet the following conditions.

Let X_{At}, X_{Bt} and X_{Ct} be the tth week energy of raw materials A, B and C supplied by the supplier, so we have the following constraints on inventory:

$$\frac{X_{At}}{0.6}+\frac{X_{Bt}}{0.66}+\frac{X_{Ct}}{0.72}\geq 5.64\times 10^4 \tag{12}$$

Among them, X_{At} is the inventory of raw materials in week t A, X_{Bt} is the inventory of raw materials in week t B, and X_{Ct} is the inventory of raw materials in week t C. The right side indicates that it is higher than the maximum production capacity of the production enterprise 56400 cubic meters.

(3) Inventory to Maintain Production

Due to the limited production scale of the enterprise and the maximum capacity of 28200 cubic meters per week. In order to clearly give the market supply and demand relationship, we believe that the market supply and demand relationship of the enterprise is stable and there will be no market overcapacity. Weekly production capacity is constrained as follows:

$$\frac{E_{At}}{0.6}+\frac{E_{Bt}}{0.66}+\frac{E_{Ct}}{0.72}=2.82\times 10^4 \tag{13}$$

(4) Supplier i 's Supply Capacity

Assuming that there are 50 suppliers, this paper divides 240 weeks into 10 cycles with 24 weeks as a cycle. Then, we visualize the historical supply data and find that some suppliers have obvious supply rules, as shown in the figure 1 and figure 2:

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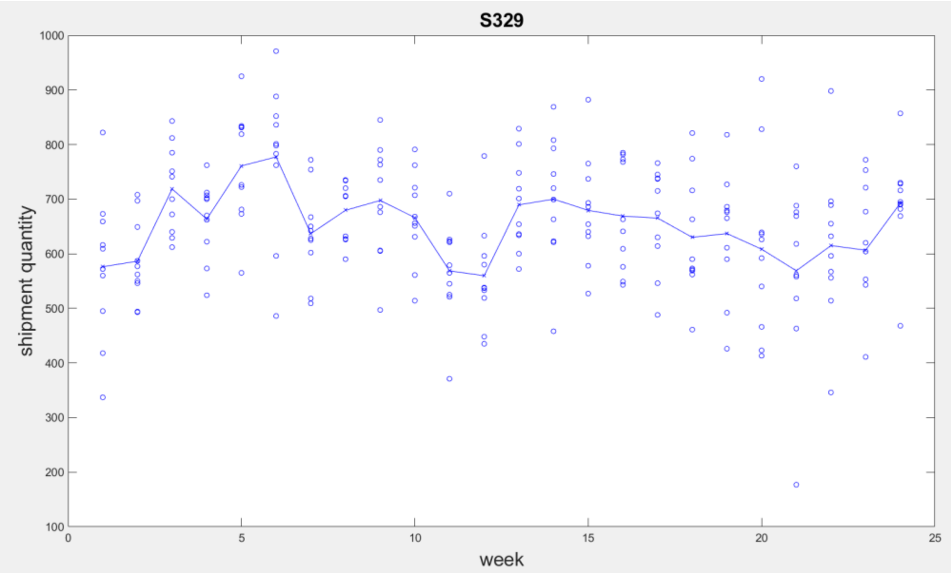

Figure 1: S329 supplier supply rule

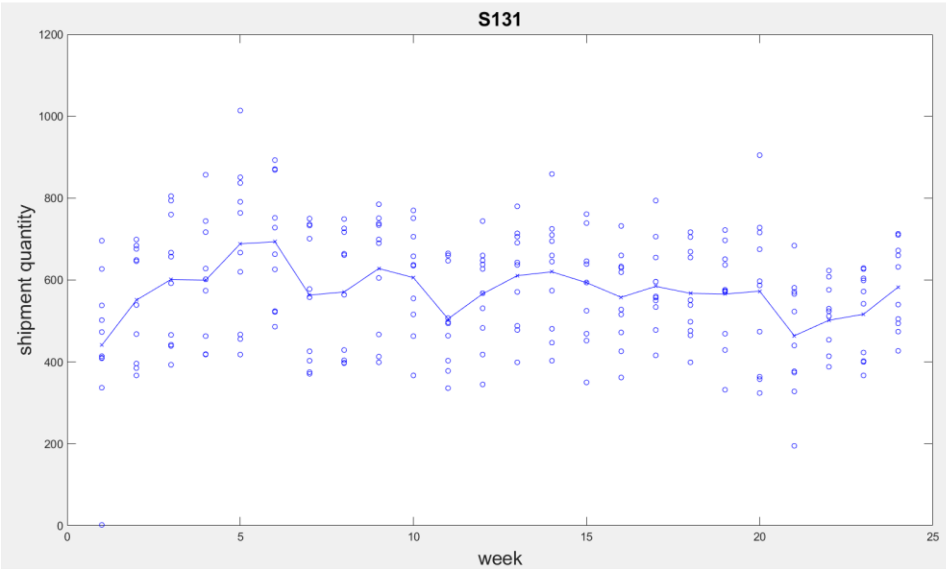

Figure 2: S131 Supplier supply rule

As shown in the above figure, the two suppliers in the past 240 weeks of supplier data, you can find that the supplier' s supply has the law of supply. In this regard, every 24 weeks for a supply cycle, each supplier in 10 cycles of supply data as a supplier supply capacity range, that is, expressed as:

$$z_{i,t}^{\min} \le z_{i,t} \le z_{i,t}^{\max} \tag{14}$$

$z_{i,t}^{\min}$ is the average minimum supply of supplier i in week t over the past 10 cycles, and $z_{i,t}^{\max}$ is the average maximum supply of supplier i in week t over the past 10 cycles.

2.2.2. Objective Function

The objective function of this problem can be transformed into an optimal solution that satisfies the constraints, that is, we require to solve the most economical ordering scheme while considering the weekly output and inventory of the enterprise. This can help businesses develop a most economical ordering plan. As the three types of raw materials transportation and storage of the same unit cost, we do not consider the cost here. Let z be the total price of the raw material ordering scheme, the unit price of class c raw material is X, the unit price of class b raw material is $1.1X$, and the unit price of class a raw material is $1.2X$. The function of the objective programming model is:

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$$\min z = X(1+0.2)\sum_{i=1}^{m} x_i + X(1+0.1)\sum_{i=1}^{u} y_i + X\sum_{i=1}^{t} z_i \tag{15}$$

$$\left(\frac{a_i \sum_{i=1}^{m} X_A}{0.6} + \frac{b_i \sum_{i=1}^{u} X_B}{0.66} + \frac{c_i \sum_{i=1}^{t} X_C}{0.72}\right)(1-\alpha_i) \ge 2.82\times 10^4 \tag{16}$$

$$\frac{X_{At}}{0.6} + \frac{X_{Bt}}{0.66} + \frac{X_{Ct}}{0.72} \ge 5.64\times 10^4 \tag{17}$$

$$a_i, b_i, c_i = \begin{cases} 1 & \text{Select the supplier} \\ 0 & \text{Do not select this supplier} \end{cases} \tag{18}$$

$$\frac{E_{At}}{0.6} + \frac{E_{Bt}}{0.66} + \frac{E_{Ct}}{0.72} = 2.82\times 10^4 \tag{19}$$

$$z_{i,t}^{\min} \le z_{i,t} \le z_{i,t}^{\max} \tag{20}$$

2.3. Optimization Model of Transshipment Scheme Based on 0-1 Integer Programming

2.3.1. Objective Function

This problem can still be transformed into an optimal solution that satisfies the constraint conditions. That is, while we solve the minimum transshipment loss, we must consider the number of transporters and the transport capacity of the transporter. This can formulate a transshipment plan with the least loss for the enterprise. Let the loss be *z*, the loss rate of the *j*th transporter in the *k*th week. The function of the goal programming model is:

$$\min z = \sum_{k=1}^{24}\sum_{i=1}^{8} \frac{x_{i_j^k}}{0.6} m_i^{kt} t_j^k + \sum_{k=1}^{24}\sum_{i=1}^{8} \frac{y_{i_j^k}}{0.66} m_i^{kt} t_j^k + \sum_{k=1}^{24}\sum_{i=1}^{8} \frac{z_{i_j^k}}{0.72} m_i^{kt} t_j^k \tag{21}$$

2.3.2. Constraint Condition

(1) Number Constraint

In order to achieve the optimal goal, we consider that the raw materials supplied by a supplier every week are transported by only one transporter. Let m_i^{kl} be the ith supplier's supply in the kth week is transported by the lth transporter, and a_i is whether to choose the transporter in the kth week. Therefore, we impose the following constraints on the number of transporters:

$$m_i^{kl} \begin{cases} 1 & \text{Select the } l\text{th transporter} \\ 0 & \text{Do not Select the } l\text{th transporter} \end{cases} \tag{22}$$

(2) Capacity constraint

In order to optimize the target, considering the transport capacity of each transporter is 6000 cubic meters / week, let M^{ik} is the *i*th supplier in the kth week of any one supplier *i* in week *k*, so we have the following constraints on the transport capacity of the transporter:

$$\sum_{i=1}^{8} a_i = 1, \quad \forall M^{ik} \le 6000 \tag{23}$$

2.4. Multi-objective programming based on NSGA-II algorithm

The order plan model is composed of 24 multi-objective programming models. The constraints of the weekly planning model are affected by the order plan of the previous week. It is mainly reflected in the

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difference of weekly cargo receiving volume and the difference of weekly freight loss, which leads to the change of inventory. The weekly order plan is affected by the production consumption of the previous week. The transshipment model is also composed of 24 multi-objective programming models, based on the order plan of this week. When solving the ordering and transshipment scheme, the t-1 week ordering scheme is first obtained. Based on the required ordering scheme, the transshipment scheme of this week is obtained, and then the t-th week ordering scheme is updated. In this regard, we use multi-objective genetic algorithm to solve.

Multi-objective genetic algorithm is an evolutionary algorithm used to analyze and solve multi-objective dynamic optimization problems. Its core is to coordinate the relationship between each objective function, so as to find the optimal solution set that makes each objective function reach a relatively large (or relatively small) function value as much as possible. NSGAII is a multi-objective genetic algorithm with the greatest influence and the widest application. Because of its simpleness, effectiveness and obvious superiority, the algorithm has become one of the basic algorithms in multi-objective optimization problems.

It proposes a fast non-dominated sorting algorithm, which reduces the complexity of calculating the non-dominated order, so that the complexity of the optimization algorithm is reduced from the original to the number of objective functions. The crowding degree and crowding degree comparison operator are introduced, which not only overcomes the defect that the shared parameters need to be specified artificially in the NSGA algorithm, but also uses the crowding degree as the comparison criterion between individuals in the population, so that the population individuals in the quasi-Pareto domain can be evenly extended to the entire Pareto domain, thus ensuring the diversity of the population. At the same time, the elite strategy is introduced to expand the sampling space, and the parent population and its offspring population are combined together to generate the next generation population through competition. This is conducive to the maintenance of the excellent individuals in the parent generation, and ensures that those excellent individuals are not discarded during the evolution process, thereby improving the accuracy of the optimization results. And by layered storage of all individuals in the population, the best individuals will not be lost, and the population level can be rapidly improved. The algorithm flow is shown in figure 3:

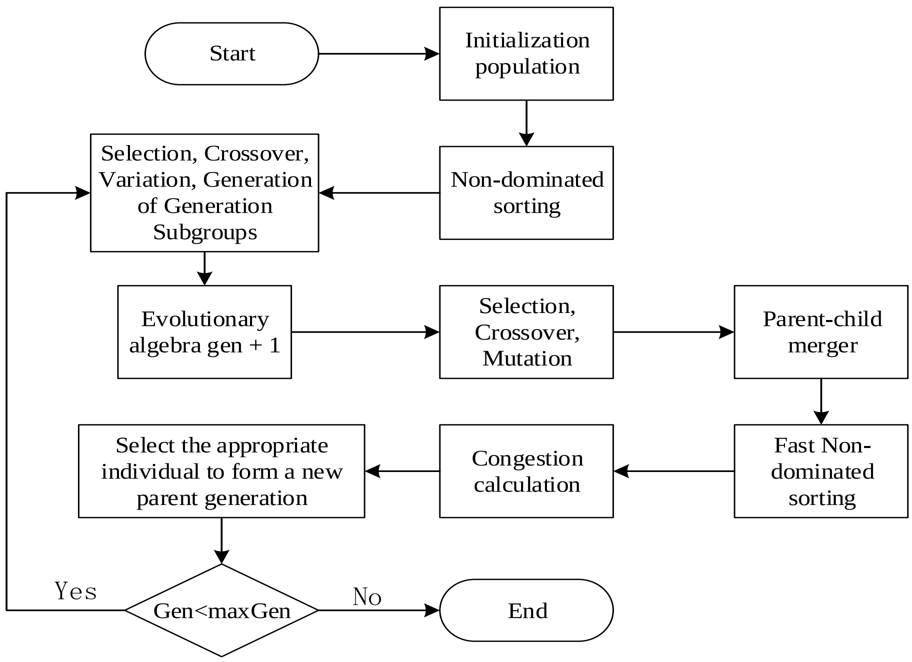

Figure 3: NSGA II Flowchart

3. Simulation Case

3.1. Rationality verification of ordering scheme

Taking into account the development of the program is random and to combine the actual, so we order the program to test the reasonableness. We assume that the company's inventory in the first week is:

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$$S_0 = 3\times 28200 - W_1 \tag{24}$$

If the inventory in week n is:

$$W_n + S_{n-1} \geq 3\times 28200 \tag{25}$$

Then the ordering scheme is reasonable.

According to the conclusion of multi-objective programming, we assume that the total order capacity per week is W_n, X_A, X_B and X_C are the supply of such raw materials supplied by the supplier, and P_A, P_B and P_C are the conversion rates of A, B and C raw materials respectively. The function of the objective programming model is:

$$W_n = a_i \sum_{i=1}^{24} X_A P_A + b_i \sum_{i=1}^{24} X_B P_B + c_i \sum_{i=1}^{24} X_C P_C \tag{26}$$

$$P = \begin{cases} \dfrac{1}{0.6} & \text{Supplier supplies class A materials} \\ \dfrac{1}{0.66} & \text{Supplier supplies class B materials} \\ \dfrac{1}{0.72} & \text{Suppliers supply class C materials} \end{cases} \tag{27}$$

$$s.t. \quad a_i, b_i, c_i = \begin{cases} 1 & \text{Suppliers corresponding materials} \\ 0 & \text{Suppliers should not correspond to materials} \end{cases} \tag{28}$$

Using MATLAB to solve the results as shown in figure 4:

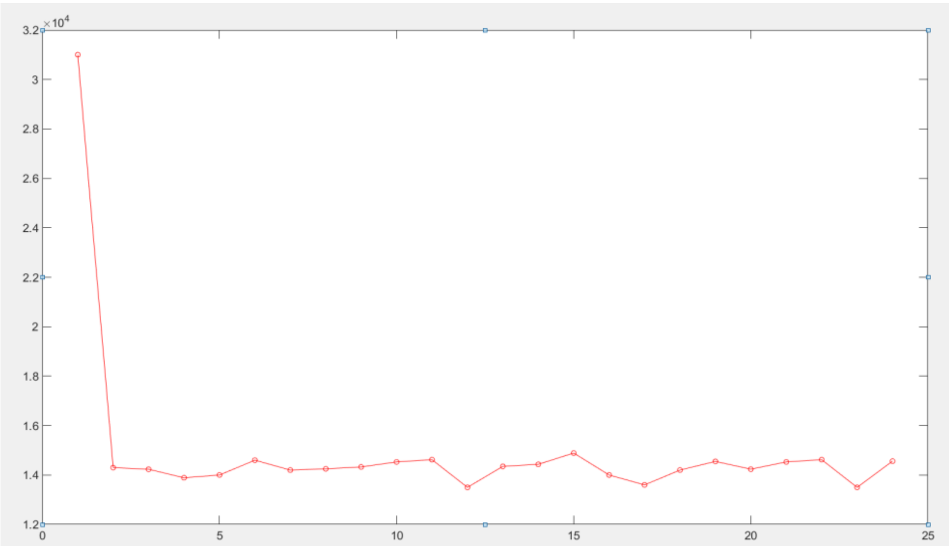

Figure 4: Rationality verification diagram of ordering scheme

We verify the rationality of the optimal ordering scheme and find that the ordering scheme satisfies the problem hypothesis and is reasonable.

3.2. The rationality verification of the transshipment scheme

Considering that the scheme is random and should be combined with the actual situation, we test the rationality of the transfer scheme.

We set P_A, P_B, and P_C as the conversion rates of raw materials in categories A, B, and C, respectively. M_i^j is the transfer volume of the j-family transporter in the i-week, and M_i^j is the total transport volume of the j-family transporter in the i-week.

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$$Q_i^j = a_i \sum_{i=1}^{402} M_i^j P_A + b_i \sum_{i=1}^{402} M_i^j P_B + c_i \sum_{i=1}^{402} M_i^j P_C \tag{29}$$

$$s.t. \quad \forall M_i^j \le 6000 \begin{cases} 1 \le i \le 24 \\ 1 \le j \le 8 \end{cases} \quad i, j \in z^+ \tag{30}$$

$$a_i, b_i, c_i = \begin{cases} 1 & \text{Supplier corresponding materials} \\ 0 & \text{Supplier does not correspond to materials} \end{cases} \tag{31}$$

T1-T24 are 24 weeks total transfers:

$$\begin{cases} T_1 = Q_{1,1} + \cdots + Q_{1,8} \\ T_2 = Q_{2,1} + \cdots + Q_{2,8} \\ \vdots \\ T_{24} = Q_{24,1} + \cdots + Q_{24,8} \end{cases} \tag{32}$$

If $W_n = T_n, (n = 1, 2, \cdots, 24)$, the transport is reasonable.

Using MATLAB to solve the results as shown in figure 5:

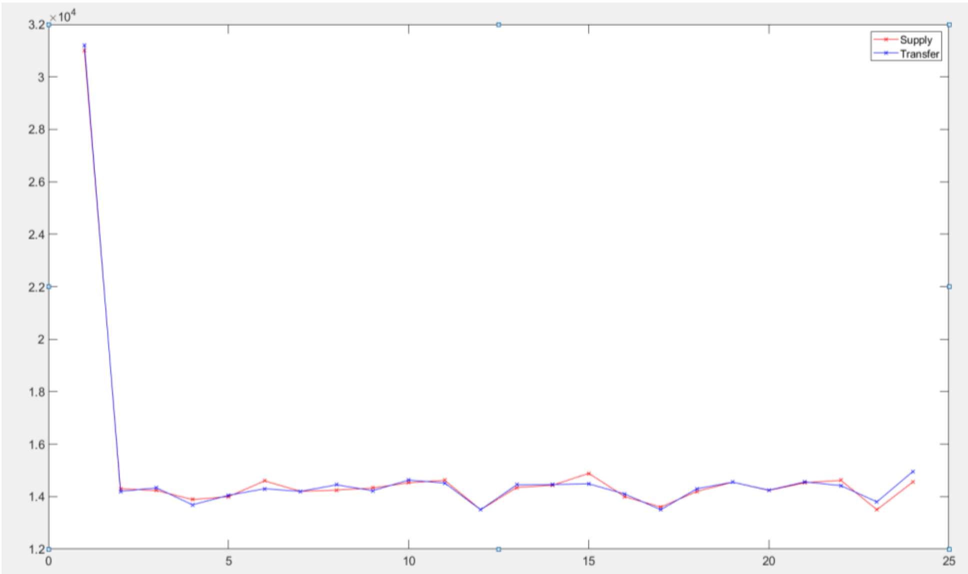

Figure 5: Verification diagram of ordering scheme rationality

We verify the rationality of the optimal transshipment scheme, and find that the graph of the order quantity of the orderer and the transshipment quantity of the transshipment scheme is very consistent, and the fluctuation is not large, which is reasonable.

4. Conclusion

The supplier's supply characteristic model established in this paper has certain universality. When giving quantitative annual total credit or other restrictive conditions, the model in this paper can be popularized in many aspects. Linear programming is an algorithm for solving multivariate optimal decision-making. It is to plan the optimal linear objective function of an object under various interrelated multivariate constraints. In this paper, the linear programming of ordering scheme and transshipment scheme makes the calculation simple and can be solved better. The NSGA-II algorithm has a good effect on complex and multi-objective optimization problems. It uses fast non-dominated sorting with elite strategy, which reduces the time complexity and greatly improves the sorting *speed*. At the same time, the elite strategy ensures that the optimal ordering scheme and transshipment scheme found will not be abandoned, which improves the search performance.

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