

Study on ordering and transportation of raw materials for manufacturing companies based on importance evaluation and single-objective optimization model

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Abstract: *Supplier preference problems and raw material ordering and forwarding problems are very common in real life. In this paper, we quantify and analyze suppliers using several indicators based on supply data, establish a supplier importance evaluation model based on the indicators, and build an optimization model by combining factors such as enterprise output, transshipment volume of transshipment providers, and raw material types to solve ordering and transshipment solutions that meet the problem. Based on the basic data, the 50 most important suppliers are identified on the basis of 402 suppliers and the results are given. In addition, for these suppliers, develop the most economical weekly ordering scheme for raw materials for the company for the next 24 weeks, and develop the least lossy transshipment scheme accordingly. An analysis of the effectiveness of the implementation of the ordering scheme and the transshipment scheme is carried out.*

Keywords: *Importance evaluation; hierarchical analysis; single-objective optimization; variable weights*

1. Introduction

A manufacturing company uses three types of raw materials, A, B, and C. The company needs to plan 24 weeks in advance for ordering and transferring raw materials. The company needs to plan 24 weeks in advance for ordering and transferring raw materials. The company has a capacity of 28,200 cubic meters per week and consumes 0.6 cubic meters of raw materials of type A, or 0.66 cubic meters of raw materials of type B, or 0.72 cubic meters of raw materials of type C per cubic meter of product. Due to the special nature of raw materials, the actual supply from suppliers may be more or less than the ordered quantity. In order to ensure the normal production needs the enterprise always acquires all the raw materials actually supplied by the supplier. During the actual transshipment by the forwarder, there is a certain loss of raw materials. Each forwarder has a transport capacity of 6,000 m³/week. Normally, raw materials supplied by one supplier per week are transported by one forwarder as much as possible. The purchase unit prices for Class A and Class B raw materials are 20% and 10% higher than those for Class C raw materials, respectively. The unit costs of transporting and storing raw materials of all three categories are the same [1].

In order to evaluate the importance of suppliers more accurately and objectively, this paper screens the suppliers with abnormal data with the help of scatter diagrams, establishes three indicators based on suppliers' supply data and enterprises' ordering data, and evaluates the importance of the three indicators based on hierarchical analysis, and assigns the weights of the three indicators according to the judgment matrix to, establish the importance evaluation model of suppliers, and select the most important 50 suppliers.

Secondly, we should establish a univariate optimization model with the least number of suppliers as the optimization objective, and solve the result by considering the production output and the transportation loss rate of the enterprise every week, and then establish a single-objective optimization model with the most economical optimization objective based on the least number of suppliers and considering the production capacity of the enterprise every week, and solve the ordering scheme, and then develop a transportation scheme with the least transportation loss according to the transportation loss rate of the forwarder, and finally validate the forwarding scheme and the ordering scheme. Finally, we validate the forwarding scheme and the ordering scheme.

2. Assumptions and notations

2.1. Assumptions

We use the following assumptions.

1. not considering the maximum storage capacity of the warehouse.
2. assuming the same quality of similar raw materials supplied by suppliers.
3. without considering the time required for transshipment.

2.2. Notations

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

Table 1: Notations

Symbols	Symbol Description
S	Supplier Importance Rating Value Index
ω_{EMS}	Weighting of EMS in S
ω_{SA}	The weight of SA in S
ω_{ST}	The weight of ST in S
F_{EMS}	Average weekly supply share of suppliers
F_{SA}	Supply Accuracy
F_{ST}	Total supply times as a percentage

3. Model construction and solving

3.1. Data pre-processing

By pre-processing the supply goods data of 402 suppliers in the annex, the proportion of the total number of weeks in 240 weeks in which 402 suppliers participated in the supply was obtained, i.e. the more the number of supply in 240 weeks, the greater the proportion, as shown in Figure 1.

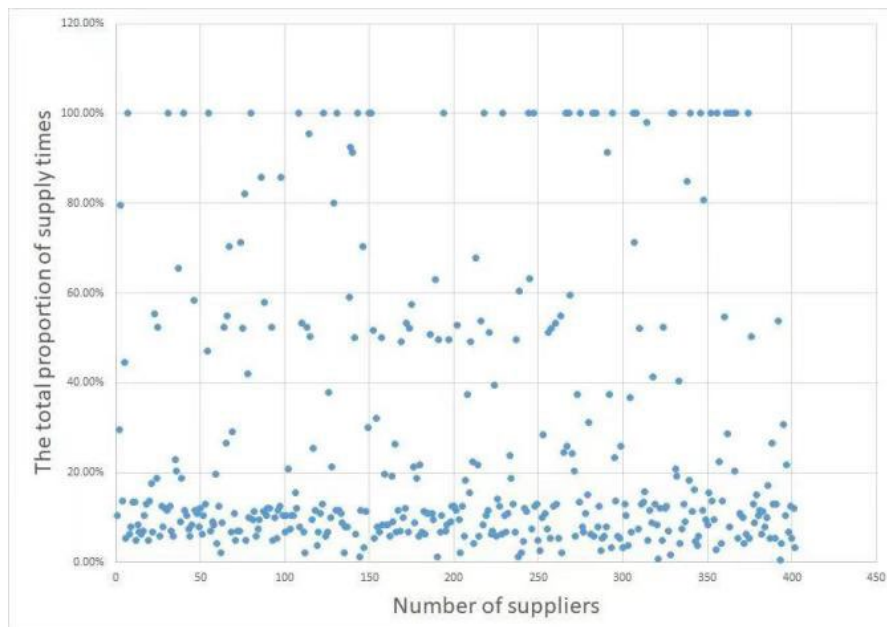


Figure 1: 402 supplier participation weeks as a percentage of total weeks supplied

We have placed the company's distrust in suppliers who have not ordered for more than 200 weeks, i.e., whose share is less than 20%, and should be These suppliers should be disregarded. Therefore, after eliminating these data from 402 suppliers, we have 135 suppliers that meet the requirements, as shown in Figure 2.

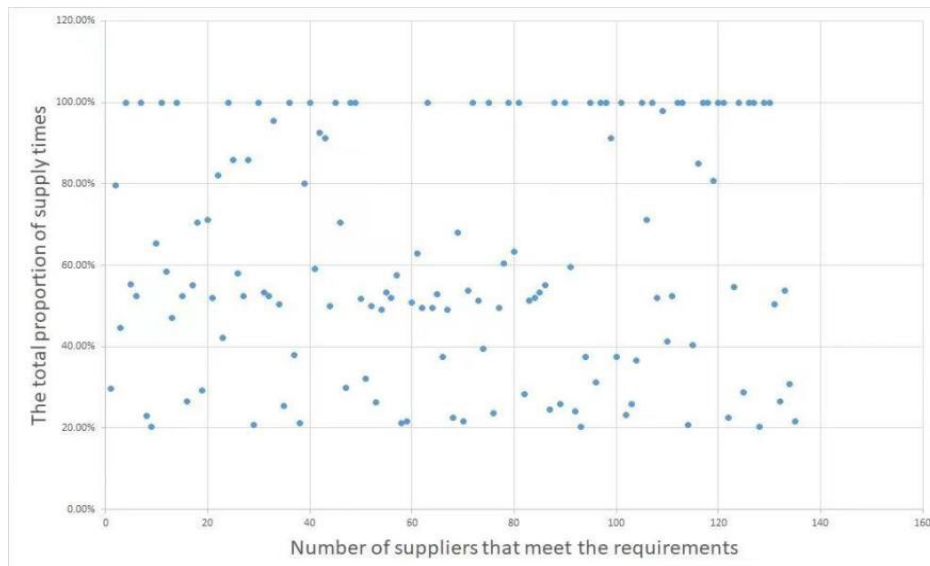


Figure 2: Percentage after raising distrust of suppliers

3.2. Supplier Importance Evaluation Model

3.2.1. Importance evaluation index calculation and processing

The average weekly supply share F_{EMS} , supply accuracy F_{SA} , and supply frequency share F_{ST} of the remaining suppliers are calculated by excel [2].

The expression of the average weekly supply share of suppliers F_{EMS} is.

$$F_{MES} = \frac{\sum_{i=0}^{135} \alpha_i}{n} \quad (1)$$

The expression for the supply accuracy F_{SA} is.

$$F_{SA} = 1 - \frac{\sum_{i=0}^{135} |\beta_i|}{n} \quad (2)$$

The expression for the total number of supply times as a percentage of F_{ST} is.

$$F_{ST} = \frac{\text{Total number of times this supplier supplied}}{\text{Total number of weeks}} \quad (3)$$

3.2.2. Importance evaluation index calculation

We develop the following mathematical model of supplier importance.

$$S = \omega_{EMS} F_{EMS} + \omega_{SA} F_{SA} + \omega_{ST} F_{ST} \quad (4)$$

Table 2: Matrix scales and definitions

The decision scale γ	Definition
1	indicates that indicator i is equally important than j
3	indicates that indicator i is equally important than j
5	indicates that indicator i is equally important than j
7	indicates that indicator i is equally important than j
9	indicates that indicator i is equally important than j
2, 4, 6, 8	indicates that indicator i is equally important than j
$1/\gamma(\gamma=1,2,,9)$	indicates that indicator i is equally important than j

The process of reallocating weights according to the importance of the actual situation using hierarchical analysis is divided into three main steps: the establishment of the judgment matrix, the

determination of evaluation indicators and the calculation of weights, and the consistency judgment. Matrix scales and definitions is shown in Table 2.

The judgment matrix D of the evaluation index is shown in equation (2).

$$D = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ d_{n1} & d_{n2} & \cdots & d_{nn} \end{bmatrix} \quad (5)$$

3.2.3. Judgment matrix creation

FEMS, SA, and ST are used as evaluation indicators, and the weights are filled in Table 4 according to the importance criteria of each indicator, and the corresponding discriminant matrix is established in equation (3).

$$D = \begin{bmatrix} 1 & 5 & 7 \\ 1/5 & 1 & 3 \\ 1/7 & 1/3 & 1 \end{bmatrix} \quad (6)$$

Table 3: Evaluation index scale

Evaluation Indicators	F_{EMS}	F_{SA}	F_{ST}
F_{EMS}	1	5	7
F_{SA}	1/5	1	3
F_{ST}	1/7	1/3	1

Evaluation index scale is shown in Table 3. Using mathematical methods, the eigenvectors of D are calculated and normalized to obtain the weights $\omega_{EMS} = 0.1884$, $\omega_{SA} = 0.081$, $\omega_{ST} = 0.730$.

3.2.4. Consistency judgment

Calculate the maximum characteristic root $\lambda_{max} = 3.0649$ of the D matrix, first calculate the consistency index CI, see equation (7), then check the index RI according to the consistency index (Table 3), and finally calculate the coefficient CR according to equation (5).

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (7)$$

$$CR = \frac{CI}{RI} \quad (8)$$

Table 4: Consistency indicators

n	1	2	3
RI	0	0	0.58

When $n = 3$, the calculated $CI = 0.3245$, check table $RI = 0.58$, the test coefficient $CI / RI = 0.055 < 0.1$, so the judgment matrix meets the consistency requirements and verifies the rationality of the weight coefficient assignment. The importance evaluation model of suppliers based on hierarchical variable weights is shown in Eq.

$$S = 0.1884F_{EMS} + 0.081F_{SA} + 0.7306F_{ST} \quad (9)$$

We can use the excel sheet to calculate each supplier's FMES, FSA, FST, bring these three data into the hierarchical variable weight supplier supply evaluation model S, we can get the supplier importance evaluation value index of each supplier, and ranking, filtered out the top 50 suppliers that is S229, S361, S108, S282, S340, S275, S329, S151, S356, S131, S306, S308, S330, S268, S194, S352, S143, S247, S284, S395, S031, S365, S040, S364, S367, S346, S348, S140, S294, S139, S037, S055, S080, S244, S218, S374, S123, S266, S338, S114, S007, S150, S307, S314, S126, S003, S291, S086, S074, S098 are the required suppliers. As shown in Table 5.

Table 5: Supplier Importance Rating S

Supplier's ID	S	Supplier's ID	S	Supplier's ID	S
S229	0.7601849	S284	0.3376093	S123	0.25991
S361	0.7248145	S395	0.3375825	S266	0.2577465
S108	0.547692	S031	0.3247881	S338	0.251805
S282	0.5346041	S365	0.3216117	S114	0.2515604
S340	0.5127094	S040	0.3080832	S007	0.2474071
S275	0.4924169	S364	0.3027039	S150	0.2473075
S329	0.4890351	S367	0.2983695	S307	0.2455575
S151	0.4850553	S346	0.2962089	S314	0.2420248
S356	0.4671728	S348	0.2920226	S126	0.2414565
S131	0.4636715	S140	0.2918297	S003	0.2409295
S306	0.4518171	S294	0.290212	S291	0.2332708
S308	0.4515807	S139	0.2894607	S086	0.2232451
S330	0.4506952	S037	0.2887317	S074	0.2133614
S268	0.4497098	S055	0.2849169	S098	0.2059976
S194	0.4111398	S080	0.2837772		
S352	0.3975422	S244	0.2835773		
S143	0.380903	S218	0.2798132		
S247	0.3473818	S374	0.2611298		

3.3. Univariate optimization model with a minimum number of suppliers as the optimization objective

3.3.1. Calculation of maximum supplier supply

To use the minimum number of suppliers to meet the weekly production needs, we need to order the maximum quantity of each supplier. We select ten maximum supply quantities from each supplier's 240 weeks of supply and average them to determine the supplier's maximum weekly supply. This is used to determine the supplier's maximum weekly supply[3]. Since the weekly supply of raw materials from one supplier is shipped by one and each forwarder has a transportation capacity of 6000 m³ /week, the maximum supplier supply is determined when When the maximum supplier supply is >6000/week, the supply quantity is reduced to 6000/week.

3.3.2. Build and solve an optimization model with the least number of suppliers as the objective

We build the following model to calculate the minimum number of suppliers needed to meet weekly production.

Optimization Goals.

$$\min(Z) = A_i + B_i + C_i \tag{10}$$

Binding Conditions.

$$\text{s.t} \begin{cases} \sum_{i=0}^{15} \frac{A_i e_i}{0.6} + \sum_{i=0}^{15} \frac{B_i e_i}{0.66} + \sum_{i=0}^{20} \frac{C_i e_i}{0.72} \geq 28200 \\ 0 \leq A_i \leq 1 \\ 0 \leq B_i \leq 1 \\ 0 \leq C_i \leq 1 \\ A_i, B_i, C_i \text{ is integer} \end{cases} \tag{11}$$

The value of Z is the minimum number of suppliers needed to meet the weekly production, and the answer is 3 after programming.

3.3.3. Build and solve the integer programming model for the most economical ordering scheme

The integer planning model with the most economical ordering solution as the objective, using only three suppliers and the merchant's maximum production volume as constraints, is based on the fact that the unit price of raw materials of category A and B is 20% and 10% higher than that of raw materials of category C, respectively[4].

Optimization Goals.

$$\min \left(1.2 \sum_{i=0}^{15} A_i P_i^A + 1.1 \sum_{i=0}^{15} B_i P_i^B + \sum_{i=0}^{20} C_i P_i^C \right) \quad (12)$$

Binding Conditions.

$$\text{s.t.} \begin{cases} \sum_{i=0}^{15} \frac{A_i P_i^A}{0.6} + \sum_{i=0}^{15} \frac{B_i P_i^B}{0.66} + \sum_{i=0}^{20} \frac{C_i P_i^C}{0.72} \geq 28200 \\ \sum_{i=0}^{15} P_i^A + \sum_{i=0}^{15} P_i^B + \sum_{i=0}^{20} P_i^C \leq 3 \\ 0 \leq P_i^A \leq 1, i = 1, 2, 3 \dots 15 \\ 0 \leq P_i^B \leq 1, i = 1, 2, 3 \dots 15 \\ 0 \leq P_i^C \leq 1, i = 1, 2, 3 \dots 20 \\ P_i^A, P_i^B, P_i^C \text{ is integer} \end{cases} \quad (13)$$

After calculation, the most economical plan is to select S348, S307 and S108 suppliers, and establish the ordering plan that 6000m3 of Class A material is ordered from S348, 6000m3 of Class A material is ordered from S307 and 6000m3 of Class B material is ordered from S108 every week.

3.3.4. Implementation Effect Analysis

$$\text{Average transportation loss rate} = \frac{\text{Total attrition rate}}{\text{Number of running weeks}} * 100\% \quad (14)$$

Obtain Table 6.

Table 6: Average loss rate of forwarders

Forwarder ID	Total number of transfers in 240 weeks	Average loss rate
T3	117	0.19%
T6	216	0.54%
T2	240	0.92%
T8	203	1.01%
T4	102	1.57%
T1	240	1.90%
T7	240	2.08%
T5	83	2.89%

According to Table 3, the raw materials supplied by one supplier per week are transported by one forwarder as much as possible. We select the top three T3, T6, and T2 forwarders with the lowest average loss rate to transport raw materials. Supplier Counterpart Forwarders is shown in Table 7.

Table 7: Supplier Counterpart Forwarders

Supplier ID	Forwarder ID
S348	T3
S307	T6
S108	T2

According to the transshipment and ordering plan we made, it is calculated that each week the enterprise can get 6000m3 of Class A raw materials supplied by S348 from T3 transshipment, and the enterprise produces 10000m3 of products, 6000m3 of Class A raw materials supplied by S307 from T6 transshipment, and the enterprise produces 10000m3 of products, and 36000m3 of Class B raw materials supplied by S108 from T2 transshipment. 6000m3 of raw materials from T2, the enterprise produces 9090m3 of products, so it can produce 29090m3 of products per week, which meets the requirement of 28200m3 production per week.

4. Conclusion

Hierarchical analysis treats the research object as a system and makes decisions according to the way of thinking of decomposition, comparative judgment, and synthesis, becoming an important tool for system analysis developed after mechanistic and statistical analysis. In actual production, the delay time

can be determined by a variety of random factors, so a fixed approximate delay time is used to replace and incorporate it into the calculation of the model in order to minimize errors.

In the actual production and ordering process, the accuracy of suppliers supplying goods is floating, and there is a gap between our calculations and the actual situation there is more room for generalization.

References

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