

# Research on Supply Chain Process Based on TOPSIS Analysis and Multi-objective Programming

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## ABSTRACT

Based on the supply chain model, under the condition of ensuring the weekly production capacity of the production enterprise, this paper works out the order plan which can complete the weekly production plan and the transfer plan which can minimize the loss of transshipment volume. Firstly, this paper establishes the supplier importance evaluation model of grey correlation degree method and TOPSIS method based on four indexes. The importance evaluation model of suppliers is established by using MATLAB software through the comprehensive use of grey correlation degree method and TOPSIS method, combined with the four indexes set. According to the order quantity and supply quantity data of 402 suppliers, the scores and rankings of 402 suppliers are calculated, and the top 20 most important suppliers are selected. Then the model of design ordering and transfer plan based on multi-objective optimization and 0-1 planning is used, and 39 suppliers are selected, which can meet the minimum number of suppliers while ensuring the production capacity of the production enterprises. Based on the 39 selected suppliers and 8 transporters, the optimal combination model of nonlinear programming is used to work out the 24-week ordering plan and transit plan.

**Keywords:** Grey relational degree, TOPSIS, multi-objective optimization

## 1. INTRODUCTION

Supply Chain Management (SCM) refers to a process in which a certain level of customer service is achieved. In order to minimize the cost of the whole supply chain system and effectively organize suppliers, manufacturers, warehouses, distribution centers and distributors[1], this paper manages the manufacture, transportation, distribution and sale of products. Supply chain management includes five basic contents: planning, purchasing, manufacturing, distribution and return. Supply chain management can directly reduce the consumption of material purchase cost, inventory cost and transportation cost, and make a great contribution to the production planning and capacity growth of production enterprises.

## 2. SUPPLIER IMPORTANCE EVALUATION INDEX SYSTEM CONSTRUCTION

### 2.1. Model preparation

The relevant data of 402 enterprises collected in this paper, at the same time, the raw materials used by

enterprises can be divided into three types, and the enterprise arranges production according to 48 weeks every year[2]. The company needs to make a 24-week raw material ordering and transshipment plan in advance according to the weekly production capacity.

### 2.2. System building

Firstly, establish a detailed definition of supplier importance evaluation index, and then establish a model of supplier importance degree.

(1) Stability of supply P: Supply stability P is defined as the variance of the ratio of weekly supply quantity delivered by the supplier to the order quantity of the manufacturer. It represents the stability degree of raw materials provided by the supplier under different orders of the manufacturer in 240 weeks. The smaller this index is, the higher the stability degree of raw materials provided by the supplier is; otherwise, the lower it is. According to this index, the manufacturer can choose the supplier with high stability to supply.

$$P = \sum_{i=1}^{240} \left( \frac{x_{ai}}{x_{bi}} \right)^2 / 240 \tag{1}$$

(2) Order frequency Q: The number of times a manufacturer purchases raw materials from a supplier in 240 weeks divided by 240. It represents the order preference degree of manufacturers to different suppliers in 240 weeks. The larger this index is, the higher the preference degree of manufacturers to this supplier is, and the more important it is to the production of products of manufacturers.

$$Q = \frac{d}{240} \tag{2}$$

(3) Error rate : Define as the mean value of the absolute value of the difference between supply quantity and order quantity and the ratio of order quantity.

$$\alpha = \left( \sum_{j=1}^{240} \frac{|x_{bj} - x_{aj}|}{x_{aj}} \times 100\% \right) / 240 \tag{3}$$

(4) Order completion rate  $\beta$ : Order completion rate  $\beta$  is defined as the ratio of the number of times the supplier's supply quantity is greater than or equal to the order quantity (except 0 order quantity) to the number of orders.

$$\beta = \frac{l-d}{d} \times 100\% \tag{4}$$

### 3. IMPORTANCE RATING MODEL BASED ON GREY CORRELATION TOPSIS METHOD

#### 3.1. Grey relational degree evaluation model construction

First, determine the comparison object and reference sequence. In this paper, 402 suppliers were collected as evaluation objects, which were recorded as a series of  $a_i = \{a_i(k) | k=1,2,3,4\}$ ,  $i=1,2,\dots,402$ . There are four evaluation criteria: supply stability P, order frequency Q, error rate  $\alpha$ , order completion rate  $\beta$ . The rating standard is a series:  $a_0 = \{a_0(j) | j=1,2,3,4\}$ .

Secondly, set the weight sequence of the evaluation index  $w_i = \{w_1, w_2, \dots, w_{402}\}$ , and meet  $w_i > 0$ . The sum of weights is 1, but the subjective view is that there is no difference between 402 enterprises, so 402 enterprises have equal weight[3].

Calculate the grey correlation coefficient after standardizing the evaluation index.

$$\xi_i(k) = \frac{\min_s \min_t |a_0(t) - a_i(t)| + \rho \max_s \max_t |a_0(t) - a_i(t)|}{|a_0(k) - a_i(k)| + \rho \max_s \max_t |a_0(t) - a_i(t)|} \tag{5}$$

To compare the correlation coefficient of the sequence to the reference sequence on the Kth index, name the  $\min_s \min_t |a_0(t) - a_i(t)|, \max_s \max_t |a_0(t) - a_i(t)|$  two-stage minimum difference and two-stage maximum difference respectively. Generally speaking, the greater the resolution coefficient, the greater the resolution; The smaller the resolution, the smaller the resolution[4].

Then the grey weighted correlation degree was calculated.

$$r_i = \sum_{k=1}^4 w_k \xi_i(k) \tag{6}$$

$r_i$  is the grey weighted correlation degree of the  $i$ th evaluation object to the ideal object.

Rank the evaluation objects according to the gray weighted correlation degree, and establish the correlation order of the evaluation objects. The greater the correlation degree, the better the evaluation result[5].

#### 3.2. System building

Due to different directions of indicators, delivery rate P is a very small indicator, order frequency Q, order quantity B, supply quantity D are very large indicators. So it is necessary to convert the very small indicator into a very large indicator. For 402 suppliers and 4 indicators that have been forward, the following forward matrix can be formed.

$$Y = \begin{bmatrix} y_{11} & y_{12} & \dots & y_{1j} \\ y_{21} & y_{22} & \dots & y_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ y_{i1} & y_{i2} & \dots & y_{ij} \end{bmatrix}, i=1,2,\dots,402, j=1,2,3,4 \tag{7}$$

The normalized matrix for this is called H, where each entry is

$$H_{ij} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{402} y_{ij}^2}}$$

Then construct a standardized matrix for 402 suppliers and 4 positive indicators, define the maximum and minimum values and the distance between them.

$$h^+ = \{h_1^+, h_2^+, \dots, h_j^+\} = (\max\{h_{11}, h_{12}, \dots, h_{1n}\}, \max\{h_{21}, h_{22}, \dots, h_{2n}\}, \dots, \max\{h_{j1}, h_{j2}, \dots, h_{jn}\}) \tag{8}$$

$$h^- = \{h_1^-, h_2^-, \dots, h_j^-\} = (\min\{h_{11}, h_{12}, \dots, h_{1n}\}, \min\{h_{21}, h_{22}, \dots, h_{2n}\}, \dots, \min\{h_{j1}, h_{j2}, \dots, h_{jn}\}) \tag{9}$$

Then the score of the I evaluation object is calculated. All the scores are normalized to get the score of the analysis.

$$s \tan d_s = \frac{S_i}{\sum_{i=1}^{402} S_i} \tag{10}$$

### 3.3. Model solving

As a result, the enterprise scores of the above two models can be obtained in order to prevent the evaluation of one model from being too one-sided. Therefore, according to the grey correlation degree and the two scores obtained by TOPSIS, the comprehensive

ranking under the two evaluation methods is obtained as the final importance rating after summation and simple average.

According to the importance rating model of grey correlation degree TOPSIS method, 20 suppliers which are the most important to ensure the production of enterprises are obtained.

**Table 1.** Top 20 rankings

Supplier ID	Material classification	Synthesis	Ranking
S282	A	0.003726	1
S284	C	0.003725	2
S306	C	0.003687	3
S275	A	0.003681	4
S329	A	0.003673	5
S229	A	0.003672	6
S194	C	0.00367	7
S340	B	0.00367	8
S268	C	0.003667	9
S247	C	0.003666	10
S356	C	0.003664	11
S365	C	0.00366	12
S151	C	0.003647	13
S108	B	0.003643	14
S031	B	0.003624	15
S352	A	0.003623	16
S364	B	0.003616	17
S131	B	0.003606	18
S330	B	0.003593	19
S361	C	0.003592	20
S282	A	0.003726	1
S284	C	0.003725	2
S306	C	0.003687	3
S275	A	0.003681	4

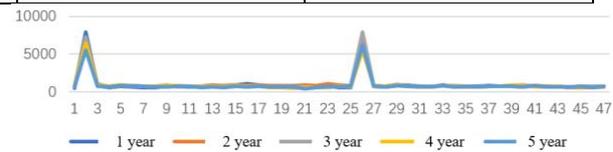
## 4. OPTIMAL MODEL OF SUPPLY CHAIN

### 4.1. Least supplier model

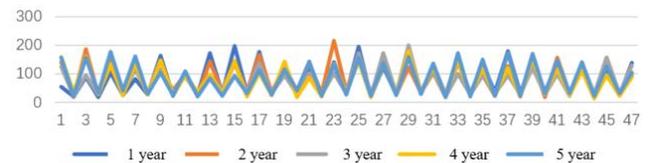
In this paper, firstly, several kinds of raw materials are modeled and analyzed. Through the supply quantity of suppliers in the past five years, it can be found that the quantity of raw materials supplied by each supplier at the corresponding time point each year has a certain regularity. Therefore, we set an upper limit G for each supplier in a certain week, which is the weighted sum of the maximum and mean of each supplier in that week in each year. And because of the ordering plan for the next 24 weeks, we select the first half of each year (24 weeks) for analysis.



**Figure 1** Five-year supply of A raw materials



**Figure 2** Five-year supply of B raw materials



**Figure 3** Five-year supply of C raw materials

The maximum supply volume MAX is the maximum supply volume of each supplier in a certain week in each year for the past five years. That is, the weekly supply limit of suppliers supplying A, B and C raw materials is matrix MAXA, MAXB, MAXC respectively.

The choice of 402 suppliers for 24 weeks was made into a matrix as the decision variables of this question, forming a 0-1 variable matrix. The value of each

position can only be 0 or 1, indicating that the supplier was selected and the purchase was based on the maximum supply quantity or not.

$$S = \begin{bmatrix} \lambda_{1,1} & \dots & \lambda_{1,j} \\ \vdots & \ddots & \vdots \\ \lambda_{i,1} & \dots & \lambda_{i,j} \end{bmatrix}, \lambda_{i,j} = \begin{cases} 0 & \text{the supplier is not selected} \\ 1 & \text{the supplier is selected} \end{cases} \quad (11)$$

Set up objective function:

$$\min Z_1 = \text{num} \left( \sum_{j=1}^{24} (S_{i,j}) \neq 0 \right) \quad (12)$$

To ensure the normal production, the enterprise should try to maintain at least two weeks of raw material inventory for production needs. The specific mathematical expression of 402 enterprises in 24 weeks is:

$$\sum_{j=1}^{24} \sum_{i=1}^{402} \lambda_{i,j} C_{i,j} \times 99\% \geq 5.64 \times 10^4 + \sum_{j=0}^{23} j \cdot 2.82 \times 10^4 \quad (13)$$

As a result, the ranking table of supplier raw materials can be obtained.

Table 2. Supplier list

S037	S040	S055	S074	S086	S108	S114	S126	S131	S139
S140	S143	S150	S151	S194	S201	S208	S210	S229	S268
S273	S275	S282	S284	S291	S306	S307	S308	S329	S330
S338	S340	S348	S352	S356	S361	S364	S365	S395	

4.2. The most economical ordering plan and the least loss of transshipment plan

For 39 suppliers of the previous model, continue to optimize. The objective function is expressed as:

$$\min Z_2 = \sum_{i=1}^{24} \sum_{i=1}^{39} \lambda_{i,j} (A_{i,j} \times 1.2 + B_{i,j} \times 1.1 + C_{i,j} \times 1) \quad (14)$$

In order to ensure the normal production needs, the enterprise should try to maintain at least two weeks of production demand raw material inventory. The corresponding capacity should be greater than or equal to 56,400 cubic meters.

$$99\% \times \sum_{j=1}^{24} \sum_{i=1}^{39} \lambda_{i,j} C_{i,j} \geq 5.64 \times 10^4 + \sum_{j=0}^{23} j \cdot 2.82 \times 10^4 \quad (15)$$

4.3. Order plan and transshipment plan with minimum loss

Let the attrition rate of each transporter in the next week be  $\omega_{\mu,j}$ . Establish a matrix of 8 rows and 39 columns with the supplier.

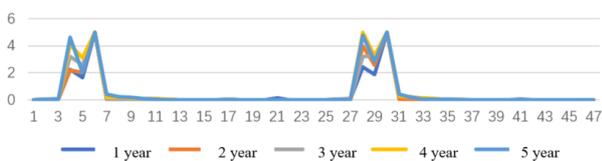


Figure 4 Five-year loss rate of transporters

$$S_z = \begin{bmatrix} \theta_{1,1} & \dots & \theta_{1,i} \\ \vdots & \ddots & \vdots \\ \theta_{\mu,1} & \dots & \theta_{\mu,i} \end{bmatrix} \quad (16)$$

Examine which transporter each supplier cooperates with each week, and finally combine the loss rate of the transporter in that week to get the final result. And there is no progressive relationship between weeks here, the goal is to minimize the loss of weekly transfer.

$$\min Z_3 = \omega_{\mu,j} \cdot S_z \cdot \begin{pmatrix} A_{i,j} \\ B_{i,j} \\ C_{i,j} \end{pmatrix}, j = 1, 2, \dots, 24 \quad (17)$$

Priority should be given to transporters with low loss rate. For suppliers with a supply volume greater than 6000, priority should be given to filling up those with low loss rate. If you fill in other transporters, for suppliers whose supply is less than 6000, a supplier can only be transported by one transshipment company per week. At the same time, there must be a transshipment company to help it transship.

$$\sum_{k=1}^8 \theta_{k,j} = 1, j = 1, 2, \dots, 24 \quad (18)$$

5. CONCLUSION

Focusing on the supply and transportation process, this paper works out an order plan that can complete the weekly production plan and a transfer plan that

minimizes the loss of transshipment volume. First of all, based on the supplier importance evaluation model of grey correlation degree method and TOPSIS method of four indicators, the supplier importance evaluation model is established by using MATLAB software through the comprehensive use of grey correlation degree method and TOPSIS method, combined with the set four indicators. As a result, the order quantity and supply quantity data of 402 suppliers can be obtained, and the scores and rankings of 402 suppliers are calculated. Finally, the model of design ordering and transfer plan based on multi-objective optimization and 0-1 planning is used, and 39 suppliers are selected, which can meet the minimum number of suppliers while ensuring the production capacity of the production enterprises. Based on the 39 selected suppliers and 8 transporters, the nonlinear programming optimal combination model is used to develop a 24-week ordering plan and transit plan.

The method used in this paper avoids a large number of operations of data, and the requirements for data are not very high, in addition, it is also applicable to the number of samples, or whether the sample size is regular or not, and there will be no discrepancy between the results of quantitative analysis and qualitative analysis. This paper comprehensively considers the stability of supply, order completion rate, order frequency and error rate, and takes into account the reputation of suppliers, the preferences of production enterprises and other suppliers. At the same time, this paper takes into account the nature of suppliers and production enterprises, and evaluates the importance of suppliers to production enterprises more objectively and in many aspects. At the same time, the TOPSIS method is used to evaluate each observation target through the subjective introduction of weights by the evaluator, and multiple indicators of objective data can also be analyzed to make the evaluation effect more objective.

## REFERENCES

- [1] Luo Yuhao. Supplier selection and Evaluation of A Company based on Entropy weight hierarchy method and BP Neural Network [D]. Guangxi University, 2020.
- [2] Yang Feifei. Research on Enterprise Purchasing and inventory Management from the Perspective of supply chain-- A case study of Beijing An Enterprise [J]. *Modern Commerce*, 2021 (15): 91-93.
- [3] Cao Shuai, Wang Chenggang, Zhang Yonglin, Sheng Xuedong, Cui Zhiyong, Zhao Jiyong. Determination of mining method of gently inclined thin vein based on coupled grey correlation degree TOPSIS method [J]. *Non-ferrous Metals (Mining part)*, 2014: 66 (02): 28-33.
- [4] Sun Yue, Wu Qiong, Li Qifen, Ren Hongbo, Yang Yongwen. Multi-objective operation optimization of ice storage system considering cost and energy consumption [J]. *Cryogenic and superconducting*, 2021. 49 (08): 58-65.
- [5] He Huiwen. Study on the factors affecting the purchasing cost of building materials and the method of determining weight vector [D]. Xiangtan University, 2016.