Research on procurement scheme and transport scheme based on TOPSIS algorithm and multi-objective linear programming

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Abstract. This paper ranks and selects suppliers based on their importance while providing the most economical ordering solution and the least lossy forwarding solution under meeting the enterprise capacity requirements. In this paper, four indicators are selected to measure the supplier's supply characteristics, and the entropy weight method is used to determine the weight of each indicator. The evaluation model is constructed using the TOPSIS algorithm to determine the importance of the supplier by calculating the distance from the sample to the ideal solution and the negative ideal solution. Then this paper uses 0-1 planning to establish a linear objective function with whether to choose one supplier as the decision variable and solves with a genetic algorithm to derive the need for at least 162 suppliers. Finally, the most economical ordering solution planning model is established, and the cost function is built and solved to find the ordering solution at its minimum value. Based on the most economical ordering solution, the least loss transshipment solution is developed, and the least loss transshipment solution planning model is developed to obtain the total loss function of raw materials and solve for the minimum value of the transshipment solution with the decision variable of whether to choose this transshipment provider. The final ordering solution obtained using the model in this paper saved approximately 9.1% of production costs, and the designed transportation solution reduced losses by 4.5%.

Keywords: evaluation of supply characteristics; TOPSIS algorithm; 0-1 planning; genetic algorithm.

1. Introduction

Construction and decorative panels enterprises are fundamental in the production and manufacturing enterprises. As an essential material production sector, it has a close relationship with the development of the national economy[1]. Raw material procurement is the first link of enterprise products, which directly determines the quantity and quality of the enterprise's products, and is crucial for every enterprise, especially for construction manufacturing enterprises[2]. For this kind of manufacturing enterprise, if they cannot get enough raw materials, they cannot finish their products on time and quantity. They may face the risk of losing customers and markets or even defaulting on contracts, so they have to carefully select suppliers and forwarders to purchase enough raw materials to meet their production capacity[3].

On the other hand, the cost of raw material procurement accounts for a large part of the total cost and has a crucial impact on profitability [4]. In this paper, we study how to analyze and evaluate the supplier's supply characteristics quantitatively and rank and select suppliers after making the evaluation. It also analyzes how to give the most economical ordering solution and the least transportation solution to meet the enterprise capacity requirements.

2. Establishment Of Models

2.1 Establishment of Evaluation model

2.1.1. Selection of supply characteristic variables

This paper adopts four indicators to quantify the supplier's supply characteristics, namely average supply quantity, supply material unit capacity usage, supply volatility, and supply risk.

Average supply quantity $\bar{g}_s(t)$ is an important supply characteristic of a supplier, and it reflects its average output of raw materials in a cycle. Let the supply of the s-th supplier in week t be $g_s(t)$, then the average supply of the sth supplier in a cycle is $\bar{g}_s(t)$.

$$\bar{g}_s(t) = \frac{\sum_{t=1}^{d} g_s(t)}{d} \tag{1}$$

The quality of supply is expressed in terms of the unit capacity usage w_s of the supplied material. Since each supplier supplies different types of materials, the conversion capacity consumption rate of different types of materials is different, and the raw material with the smallest consumption rate, the raw material with a lower production unit capacity usage, is considered to be of better quality.

$$w_s \in \{a = 0.6, b = 0.66, c = 0.72\} \tag{2}$$

The volatility k_s of the supplier's ability to supply is critical as companies consider securing long-term capacity requirements when ordering. The less volatility, the more stable and secure the supplier's supply is.

$$k_s = \frac{\sum_{t=1}^{d} (g_s(t) - \bar{g}_s(t))^2}{d} \tag{3}$$

The company's order quantity is not necessarily equal to the supplier's delivery quantity, assuming that the supplier's delivery quantity is not affected by the order quantity size and that the supplier's ability to meet the company's order quantity is only related to the supplier's delivery risk $q_s(t)$, but not to the company's order quantity size.

Since the company maintains a raw material inventory that can meet at least two weeks of production demand, the supplier's delivery rate is critical. If the supplier delivery rate is too low, there will be a shortage of raw materials to meet the company's capacity requirements. The higher the supplier's delivery rate, the lower the supply risk; the lower the delivery rate, the higher the supply risk. [5] If the delivery exceeds the order quantity to form an excess supply, the supply risk is 0. For the supplier that the enterprise does not order in the tth week, the supply risk is uniformly considered to be 0.5.

$u_s(t)$ is the firm's order quantity to the third supplier on week t. Then $q_s(t)$ is the supply risk of the s-th supplier on week t.

$$q_s(t) = \begin{cases} 1 - \frac{g_s(t)}{u_s(t)},\ \mu_s(t) > 0 \text{ and } g_s(t) < u_s(t) \\ 0,\ \mu_s(t) > 0 \text{ and } g(t) > \mu_s(t) \\ 0.5, \mu_s(t) = 0. \end{cases} \tag{4}$$

2.1.2. Entropy weighting method to calculate weights

The entropy weighting method is an objective method to determine the value of each indicator by the degree of variation of the value of evaluation indicators and the amount of information presented, which is better to avoid the influence of subjective weighting on the quantitative results of supply characteristics. The principle of the entropy weighting method is based on the degree of variation of indicators. The greater the influence of indicators, the higher the degree of variation, the higher the corresponding weights, and the higher the degree of influence.

In data processing, the data are firstly normalized and normalized, and all the data are non-negative. Let x_j be the information entropy of the j-th indicator, we selected four indicators and should find four information entropies. Meanwhile, let p_{sj} be the proportion or probability of the s-th supplier in the j-th indicator, and i,j∈Z.

$$p_{sj} = \frac{z_{sj}}{\sum_{i=1}^{n} z_{sj}} \tag{5}$$

$$\mathrm{x}_j = -\frac{1}{\ln\ n}\sum_{i=1}^{n} p_{sj} \ln\left(p_{sj}\right) \tag{6}$$

where z_{sj} denotes the normalized and normalized data. z_{sj} is the s-th data in indicator j.
To measure information positively, we introduce the information utility value D_j.

$$D_j = 1 - \mathrm{x}_j \tag{7}$$

The final normalization of the data yields the entropy weight w_j for each indicator.

$$w_j = \frac{D_j}{\sum_{j=1}^{m} D_j}\mathrm{m}, \mathrm{j} = 1,2,3,4 \tag{8}$$

The weight values of the four indicators were found, as shown in Table 1.

Table 1. The weights of each indicator

Indicator	Weight
$\bar{g}_s(t)$	0.76770706
w_s	0.13348263
k_s	0.0009218
$q_s(t)$	0.09788851

2.1.3. Evaluation model based on TOPSIS

The TOPSIS evaluation method, also known as the superior-inferior solution distance method, is represented mainly by mathematical concept vectors[6]. It combines the weight coefficients obtained from the combination assignment with the initial decision matrix to obtain the weighted decision matrix, and the weights of the evaluation indexes affect the information and accuracy contained in the original decision matrix.

For convenience, G, W, K, and Q are used to represent the maximum values of the four indicators of average supply quantity, unit capacity usage of supply material, volatility, and supply risk, respectively; and g, w, k, and q are used to represent the minimum values of these four indicators, respectively. First, find the vector of maximum values corresponding to the four indicators.

$$Z^{+} = \{\mathrm{G}, \mathrm{W}, \mathrm{K}, \mathrm{Q}\} \tag{9}$$

The vector Z^{+} represents the ideal supplier, which is the ideal solution. Next, find the minimum value corresponding to the four indicators to form the vector.

$$\mathrm{Z}^{-} = \{g, \mathrm{w}, \mathrm{k}, q\} \tag{10}$$

The vector Z^{-} represents the least optimal supplier, which is the negative ideal solution. The rating ranking is based on the distance of the sample to the best and worst solutions. Mark the sample as:

$$\mathrm{Z} = \{g_s, w_{\mathrm{s}}, k_{\mathrm{s}}, q_s\} \tag{11}$$

Let the distance between the s-th supplier and the ideal be $\mathrm{d}_{\mathrm{s}}^{+}$, which is calculated as:

$$\mathrm{d}_s^+ = \sqrt{(\mathrm{G} - g_s)^2 + (\mathrm{W} - w_s)^2 + (\mathrm{K} - k_s)^2 + (\mathrm{Q} - q_s)^2} \tag{12}$$

Let the distance between the s-th supplier and the negative ideal be d_s^-, which is calculated as:

$$\mathrm{d}_s^- = \sqrt{(g - g_s)^2 + (\mathrm{w} - w_s)^2 + (\mathrm{k} - k_s)^2 + (q - q_s)^2} \tag{13}$$

Define the final score F for the sth supplier and calculate the formula as:

$$\mathrm{F} = \frac{\mathrm{d}_s^-}{\mathrm{d}_s^+ + \mathrm{d}_s^-} \tag{14}$$

The analysis shows that F lies between the interval [0,1]. When F is closer to 1, it means that the closer the supplier is to the ideal target, the more important the supplier can guarantee the production of the enterprise.

2.2 Establishment of Planning Model

2.2.1. Optimal Supplier Decision Model

With the decision variable of whether to choose a particular supplier, let x_s denote the sth supplier, wheres = 1, 2, 3, ..., 50.

$$\mathrm{x}_s = \begin{cases} 1, & \text{Choose this supplier} \\ 0, & \text{Do not choose this supplier} \end{cases} \tag{15}$$

Next, solve for the supplier that makes x_s =1. Assume that if a firm chooses to order from a particular supplier, it will order every week. It will minimize the number of suppliers chosen. The supplier chosen should meet the firm's capacity requirements and ensure that the firm holds an inventory of raw materials that can meet its two-week capacity requirements. Denote its capacity contribution per unit of material by N_a.

Thus, the values of N_a under different conditions can be obtained.

$$N_a = \begin{cases} 1.67 & a = A \\ 1.52 & a = B \\ 1.40 & a = C \end{cases} \tag{16}$$

Let y_{st} be the average supply quantity of the s-th supplier in the t-th week, calculated by taking 24 weeks as 1 cycle and calculating the average value of the supply quantity of the corresponding weeks of 10 cycles in total, calculated as follows.

$$y_{st} = \frac{\sum_{t=24n,n=1}^{10} x_{st}}{10} (s = 1,2,\cdots,50) \tag{17}$$

Where n denotes the number of cycles, and from the attached data, it is easy to know that a total of 10 cycles of data are given.

Let the capacity of the firm on week t be Y_t, then its mathematical expression should be:

$$F = \frac{H}{10} \tag{18}$$

$$Y_t = \sum_{i=1}^{50} x_s y_{st} N_a F \tag{19}$$

where H is the number of times the supply quantity s of the supplier at the same location corresponding to these ten cycles is greater than the average supply quantity y_{st}.

As the supplier's supply should meet the enterprise's weekly production capacity requirements, the supplier should provide raw material production capacity of not less than 28,200 cubic meters. At the same time, the enterprise's inventory stock should ensure that it can meet the production requirements of not less than two weeks as far as possible. So:

$$\begin{cases} t = 1, Y_t \geqslant 5.64 * 10^4 \text{ m}^3/\text{week} \\ 1 < t \leqslant 24, Y_t \leqslant 2.82 \text{ m}^3/\text{week} \end{cases} \tag{20}$$

2.2.2. Optimal Ordering Planning Model

In a broad sense, the so-called cost refers to the generalized resources consumed, and the generalized cost is called the generalized cost. The most economical is to minimize the generalized costs of natural and social processes [7].

For a company, the most economical goal to achieve company is actually to minimize its cost. Therefore, the cost of this paper, i.e., the purchase unit price of different materials, also considers the difference in the actual capacity contribution of materials at different prices. Suppose it costs c yuan to purchase 1 unit of Material C. Set I_a as production cost per unit capacity, then I_a= material consumption per unit capacity × unit material purchase price.

The value of I_a in the choice of material, an (a=A, B, C) can then be obtained as follows:

$$I_a = \begin{cases} 0.72c, a = A \\ 0.726c, a = B \\ 0.720, a = C \end{cases} \tag{21}$$

To find the minimum cost to the enterprise is actually to find the minimum expenditure of the enterprise. When C_t is set as just meeting the capacity requirement, the raw material procurement expenditure on week t is:

$$C_t = \sum_{i=1}^{162} x_s I_a y_{st} \quad (t = 1,2,\cdots,24) \tag{22}$$

where $C_1 = \sum_{i=1}^{2} x_s Iay_{st}$, when t=1. It is due to the need to purchase raw materials in the first week that satisfy the total capacity of the 1st and 2nd weeks. Moreover, the other weeks only need to purchase raw materials that meet the capacity of the week (t+1). Therefore, the objective function and constraint conditions are:

$$C = \min\{C_t\} \tag{23}$$

$$\begin{cases} t = 1, Y_t \geqslant 5.64 * 10^4 \text{ m}^3/\text{week} \\ 1 < t \leqslant 24, Y_t \leqslant 2.82 \text{ m}^3/\text{week} \end{cases} \tag{24}$$

2.2.3. Optimal transport scheme planning model

After developing a corporate ordering plan, it is also necessary to develop a transit plan that minimizes losses and selects how to ship to make the cost and cost effective.

Let u_{tz} denote the average loss rate of the z-th forwarder on week t (z = 1, 2, ... , 8; t = 1, 2, ... , 8; t = 1, 2, ... , 24), and let the total transfer volume of the z-th forwarder in week t be L_{tz}. Taking whether to choose a certain transporter as the decision variable, let r_{sz} represent that supplier s chooses transporter z.

$$r_{sz} = \begin{cases} 1, \quad \text{supplier s chooses transporter z} \\ 0, \text{supplier S do not chooses transporter z} \end{cases} \tag{25}$$

To find the condition satisfying $r_{sz} = 1$ is to find the transport scheme we require.

Let E_t be the total consumption of raw materials on week t, and t= 1,2... , 24, then the objective function is:

$$E = \min\{E_t\} \tag{26}$$

$$E_t = \sum_{z=1}^{8} \sum_{s=1} r_{sz} u_{tz} y_{st} \quad (t = 1,2,\ldots,24) \tag{27}$$

Since the transportation capacity of each transporter is $6000\text{m}^3/\text{week}$, and the raw materials supplied by one supplier every week should be transported by one transporter as far as possible, the constraints are as follows:

$$L_{tz} = \sum r_{sz} y_{st} \tag{28}$$

$$0 \le L_{tz} \le 6000 \tag{29}$$

$$\sum_{z=1}^{8} r_{sz} = 1 \quad \text{or} \quad \min \sum r_{sz} \tag{30}$$

Table 2. Supplier importance ranking

Supplier ID	Score	rank	Supplier ID	Score	Rank
S229	0.998582849	1	S284	0.1601193	26
S361	0.897202684	2	S037	0.155901679	27
S140	0.84717386	3	S031	0.151600365	28
S108	0.680028219	4	S365	0.148739451	29
S151	0.548553358	5	S126	0.139901919	30
S340	0.488404314	6	S040	0.132147764	31
S282	0.485617185	7	S364	0.127235856	32
S275	0.456249719	8	S367	0.121578059	33
S329	0.450698205	9	S338	0.121510919	34
S139	0.433879942	10	S055	0.116489118	35
S131	0.395659826	11	S346	0.116402518	36
S308	0.393782122	12	S266	0.112671463	37
S330	0.393085023	13	S114	0.111408865	38
S356	0.37388465	14	S007	0.111143907	39
S268	0.372648056	15	S123	0.11060195	40
S306	0.362712047	16	S150	0.106453964	41
S194	0.296542	17	S294	0.1060169	42
S348	0.276601453	18	S291	0.10557038	43
S352	0.272259716	19	S080	0.105443687	44
S143	0.255483609	20	S218	0.101975667	45
S201	0.239868516	21	S244	0.100606283	46
S307	0.238981108	22	S189	0.096159884	47
S395	0.226233928	23	S086	0.091232394	48
S247	0.183086543	24	S221	0.088754473	49
S374	0.165870281	25	S269	0.088624217	50

3. Analysis Of Results

F is the score of the evaluation model based on TOPSIS. When F is closer to 1, it indicates that the supplier s is closer to the ideal target, and the supplier can guarantee the importance of enterprise production. When F is closer to 0, it indicates that the company s is closer to the negative ideal target, and the supplier cannot guarantee the importance of the company's production. Finally, F is ranked from the largest to the smallest, and the results of the top 50 suppliers are shown in Table 2.

Genetic algorithm starts from a population that represents the potential solution set of a problem and consists of a certain number of individuals encoded by genes. Each individual is a chromosomal entity with characteristics. The algorithm starts from the initial population, according to the biological principle of survival of the fittest and survival of the fittest, and generates better and better approximate solutions through several iterations.

According to the optimal supplier decision model in this paper, genetic algorithm is used to solve the problem. Finally, taking the top 200 suppliers as samples, it is

Table 3. The weights of each indicator

SupplierID	Week 09	Week10	Week 11	Week 12
S131	628.1	605.8	505.1	566.2
S139	25.8	9.9	13.05	8.46
S151	647.4	590	240.96	266
S210	11.76	2.31	25.92	6.57
	Week 13	Week 14	Week 15	Week 16
S131	610.7	619.9	593.6	557.8
S139	15.21	9.45	16.47	7.38
S151	537.96	605.9	710.3	702.5
S210	10.83	28.88	63.39	17.72

concluded that at least 162 suppliers should be selected to meet the production needs. Some ordering schemes are shown in Table 3. We substitute the new scheme and the historical scheme into the cost function and loss function to get the implementation effect of the new scheme. The order scheme obtained in this paper saves about 9.1% of production cost, and the transport scheme designed reduces 4.5% of loss.

4. Conclusion

This paper quantifies the supply characteristics of suppliers, obtains the importance of suppliers and ranks them, and establishes an optimal decision model with decision variables and minimum as the objective function.The idea of cycle and the means of average value are adopted to solve the 24-week weekly ordering scheme and transshipment scheme, so as to avoid the large error caused by the randomness of cycle selection. The concept of risk factor is introduced to minimize the unreliability of the data after averaging the supply quantity from suppliers.

Finally, the new scheme is compared with the historical scheme by substituting cost function and loss function to get the implementation effect of the new scheme. The order scheme obtained in this paper saves about 9.1% of production cost, and the transport scheme designed reduces 4.5% of loss, which meets the production and management needs of enterprises and achieves ideal results

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