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Quantitative analysis of supply characteristics based on TOPSIS method

Ziwei Li[1,*], Qiqi Wang[2]

[1]*Economics and Management School, Anhui University of Science and Technology, Huainan, 232000, China*
[2]*School of Computer Science and Engineering, Anhui University of Science and Technology, Huainan, 232000, China*

Abstract: *The raw materials used in the production of building and decorative panel enterprises are mainly fiber materials, which are special and may have imbalance between supply and demand, so it is necessary to find suitable suppliers through quantitative analysis of supply characteristics. We consider the quantitative analysis of the supply characteristics of 402 suppliers to quantify the supply stability score, first extracted four indicators, namely, the average weekly supply value of suppliers, the maximum weekly supply, the variance of the order quantity difference, the supplier completion rate, and the four indicators integrated into the supplier's attractiveness to the enterprise, the balance of supply and demand of raw materials, the ability to ensure normal production, and then use AHP combined with entropy weighting method to the above After that, the four indicators are subjectively and objectively assigned with AHP and entropy weighting method, and then the data are adjusted and calculated to obtain the required index data.*

Keywords: *Entropy method; AHP; TOPSIS; Supply characteristics*

1. Introduction

Based on the known data of each supplier's supply category, weekly supply quantity, enterprise weekly order quantity and order category, this paper quantitatively analyzes the supply characteristics of 402 suppliers and establishes a mathematical model that reflects the guarantee of enterprise production, so as to determine the 50 most important suppliers.

We quantify the supplier supply characteristics into supply stability score, first of all, we consider and extract four indicators based on data analysis: the average value of weekly supplier supply, the maximum supply in 240 weeks, the variance of whether the weekly order quantity is reached, the probability that the supply quantity is greater than or equal to the order quantity, and the four indicators are integrated and analyzed to get the three main levels of supply characteristics: the attractiveness of suppliers to enterprises Then the entropy weighting method combined with the hierarchical analysis method is used to assign weights to the above four indicators, and finally the TOPSIS method is used to establish a mathematical model to quantify and score the supply capability of 402 suppliers, i.e. the supply stability score, and give the most important 50 suppliers.

2. Model assumptions

Hypothesis 1: The more raw materials a company orders from a supplier, the stronger the supply of a supplier is, i.e., the more attractive it is to the company.

Hypothesis 2: When an enterprise orders during the period of raw material shortage, the focus is on ensuring normal production and not selecting suppliers of specific types of raw materials.

Hypothesis 3: When the order quantity from a certain supplier is more than 6000m3/week, the enterprise will decide to choose another supplier to transfer the raw materials.

Assumption 4: The raw material is special, the supplier can't guarantee to supply strictly according to the order quantity, the actual supply quantity may be more or less than the order quantity, before the enterprise has the ability to improve the output, we assume that when the enterprise specifies the ordering and forwarding plan, only the actual supply quantity is less than the order quantity, that is, only consider the loss rate but not the overflow rate.

Assumption 5: Uncontrollable factors such as severe shortage of raw materials and significant price changes brought about by social or natural disasters are not considered within a certain period.

Assumption 6: The collected data is true and valid.

3. For model construction and solving

3.1 Modeling Preparation

3.1.1 Data Analysis

(1) Uniformity of the quantity of raw material categories supplied.

From the basic data analysis, the same volume of raw materials of categories A, B and C contribute differently to the production capacity, so it is necessary to make the data in the original Annex I consistent by A, B and C.

$$new_{-}a_{ij} = \frac{10}{11}a_{ij} \tag{1}$$

$$new_{-}a_{ij} = \frac{5}{6}a_{ij} \tag{2}$$

(2) The supplier's attractiveness to the business

We iteratively solve for the total amount of supplies to the enterprise for each supplier for 240 weeks, and then analyze the characteristics of the types of raw materials supplied by the suppliers. Using Matlab's cftool toolbox, we make the number of each supplier, the types of raw materials supplied and the corresponding total amount of supplies

Based on the results of the analysis we obtained the following information and extracted from it the indicators to solve the problem.

1) We found that the enterprise does not have a large difference in the choice of suppliers supplying different categories, and the overall difference in the odds of choosing each supplier is not significant.

2) The amount of raw materials supplied by suppliers of different types of raw materials does not vary greatly, and although the largest amount of supply occurs in category B, the overall amount of raw materials supplied to the enterprise in each category is relatively balanced.

3) Considering the above information, we temporarily disregard the enterprise's choice of raw material categories and consider them as supplying the same material, and reflect the supplier's attractiveness to the enterprise according to the average value of the quantity of raw materials supplied by suppliers in the past 5 years and the maximum value of weekly supply in 240 weeks.

(3) Balance between supply and demand of raw materials

Analyzing the data, some of the supply is large because the order quantity of the enterprise is also large, y considers the ratio of the supplier's supply is greater than or equal to the order quantity of the enterprise to measure the ability to guarantee the normal production of the enterprise. Secondly, we consider that the special characteristics of fiber materials may cause the supplier's supply to be less than the order quantity for too many weeks at a certain stage, so we allow the supply to be less than the demand, and for this reason we also introduce the size of the variance of the difference to measure the balance of supply and demand between the supplier and the enterprise.

3.2 Model building and solving

3.2.1 AHP combined with entropy weighting method to determine index weights

(1) AHP method to find the weights

Step1: Build the hierarchy

According to the above, we choose four indicators three perspectives to measure the stability of

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supplier supply, thus we will be the highest target layer J, the supplier's attractiveness to the enterprise K1, the balance of supply and demand of raw materials K2, the ability to ensure normal production of the enterprise K3 as the middle criterion layer, the average value of the supplier's weekly supply, the maximum supply in 240 weeks, the variance of whether the weekly order quantity is reached, the four indicators P1, P2, P3 and P4 of supply quantity is greater than or equal to the probability of order quantity as the bottom measure layer, as shown in Figure 1.

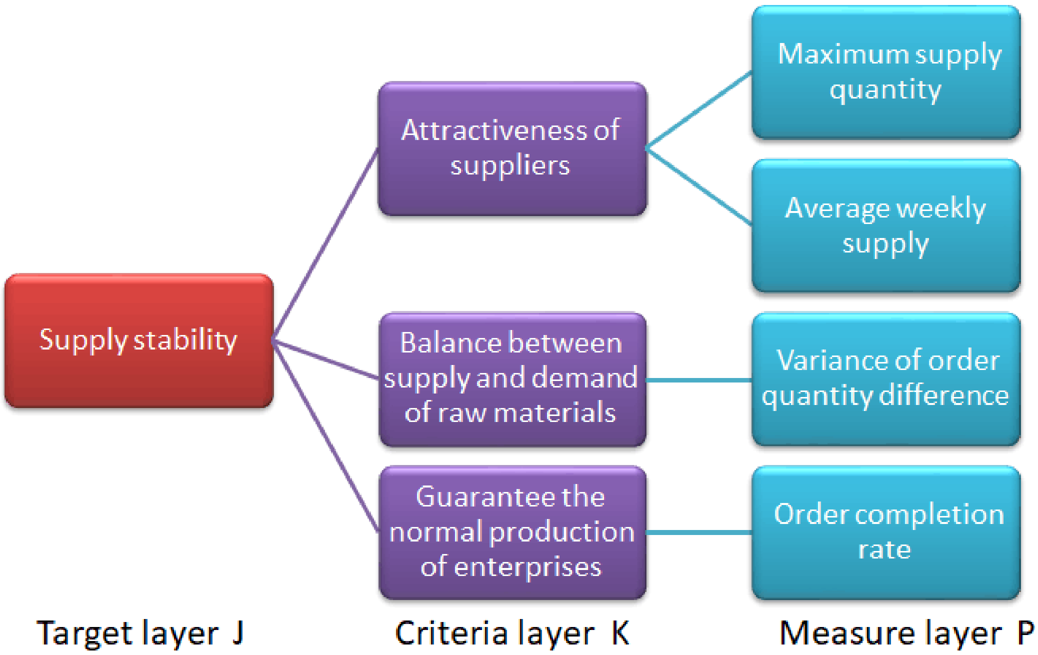

Figure 1: Hierarchical analysis method

Step2: Construct the judgment matrix and solve it

By finding information [1] to analyze the importance of indicators we combined with the scale weighting table to score the judgment matrix constructed as shown in the following table. Table 1 shows the J-K judgment matrix, and Table 2 shows the Ki-Pj judgment matrix. (where i=1,2,3 j=1,2,3,4).

Table 1: J-K judgement matrix

J	K1	K2	K3
K1	1	1/4	1/8
K2	4	1	1/3
K3	8	3	1

Table 2: Ki-Pj judgment matrix

K1	P1	P2	K2	P3	K3	P4
P1	1	4	P3	1	P4	1
P2	1/4	1				

Before seeking the indicator weights, the consistency test of the judgment matrix is needed, we find the hierarchical analysis of n and RI relationship table shown in Table 3, using the formula $CI=\frac{\lambda_{\max}-n}{n-1}$, and then according to the $CR=\frac{CI}{RI}$ solution results and 0.1 for comparison to know whether the judgment matrix passes the consistency test.

Table 3: n Relationship with RI

n	2	3	4	5	6	…
R	0	0.58	0.90	1.12	1.24	…

Step3: Deriving indicator weights

In order to make the model solution robust, we use three methods of finding weights to find the

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average of the weights, by writing the program to solve the maximum eigenvalue $\lambda_{\max}$ of J-K is 3.0183, the weights ω_i = (0.0734, 0.2564, 0.6702) T, CR = 0.0158 < 0.1 at the same time to solve the K-P layer weights are (0.8000, 0.2000) T[2]. Based on the above results, we have the total weights of the bottom four indicators P1-P4, i.e., the average value of suppliers' weekly supply, the maximum supply in 240 weeks, the variance of whether the weekly order quantity is reached, and the probability that the supply quantity is greater than or equal to the order quantity are 0.05872, 0.01468, 0.25640, and 0.6702, respectively.

(2) Entropy weight method to find weight

Step1: Difference variance normalization

We organize the table to obtain the original matrix consisting of 402 evaluation objects and 4 evaluation indicators.

$$\begin{bmatrix} 5.454545 & 0.185606 & 4.153918 & 0.7 \\ 67 & 1.1375 & 4.051241 & 0.870833 \\ 322.5 & 45.61806 & 39.52224 & 0.879167 \\ \vdots & \vdots & \vdots & \vdots \\ 7.272727 & 0.253788 & 5.884916 & 0.825 \\ 18.18182 & 0.132576 & 16.63622 & 0.7125 \end{bmatrix} \tag{3}$$

Since the difference variance is a very small (cost-based) indicator, this indicator is first normalized, and for the normalization we use.

$$\frac{1}{x} \tag{4}$$

The matrix is normalized to obtain the normalized matrix.

$$\begin{bmatrix} 5.454545 & 0.185606 & 0.240736581 & 0.7 \\ 67 & 1.1375 & 0.246837954 & 0.870833 \\ 322.5 & 45.61806 & 0.025302209 & 0.879167 \\ \vdots & \vdots & \vdots & \vdots \\ 7.272727 & 0.253788 & 0.169925965 & 0.825 \\ 18.18182 & 0.132576 & 0.060109821 & 0.7125 \end{bmatrix} \tag{5}$$

Step2: Standardization of all indicators.

In order to eliminate the effect of different metric magnitudes, the matrix that has been normalized needs to be dimensionless. The matrix normalized to it is denoted *z*. Each element in z[3].

$$z_{ij} = x_{ij} \Big/ \sqrt{\sum_{i=1}^{10} {x_{ij}}^2} \tag{6}$$

After normalization, a normalized matrix with 402 objects and 4 evaluation indicators is obtained, and the normalized matrix is normalized to obtain the normalized matrix.

$$Z = \begin{bmatrix} 0.00002368 & 0.00001107 & 0.000736127 & 0.0020119 \\ 0.0002909 & 0.00006787 & 0.000754784 & 0.0025029 \\ 0.0014001 & 0.0027219 & 0.0000773694 & 0.00252686 \\ \vdots & \vdots & \vdots & \vdots \\ 0.00003157 & 0.00001514 & 0.000519602 & 0.00237117 \\ 0.00007893 & 0.00000791 & 0.000183805 & 0.00204783 \end{bmatrix} \tag{7}$$

Step3: Calculate the information entropy of indicators and derive the weights

By calculating the information entropy.

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$$e_j = -K\sum_{i=1}^{n} p_{ij}\ln p_{ij}, K>0, K=\frac{1}{\ln n} \tag{8}$$

Obtain the information entropy value of each criterion.

$$E=(0.519722, 0.5989448, 0.826305626, 0.99919272) \tag{9}$$

According to the relationship between utility value and information entropy.

$$d_j = 1-e_j,\ \ j=1,2,3,4 \tag{10}$$

Obtain the utility value of each criterion.

$$D=(0.480278, 0.4010552, 0.173694374, 0.00080728) \tag{11}$$

By the entropy weight formula.

$$w_j=\frac{d_j}{\sum_{j=1}^{4} d_j} \tag{12}$$

Obtain the entropy weight of each criterion, i.e., the weight.

$$W_s=(0.4548799, 0.3798465, 0.164509028, 0.00076459) \tag{13}$$

3.2.2 Quantitative supply characteristics of TOPSIS scores

The final index weights *W* is obtained by averaging the weights derived from the above hierarchical analysis method and the entropy weight method[4].

$$W=(0.23477995, 0.21928325, 0.210454514, 0.335482295) \tag{14}$$

After determining the weights, construct the weighted data matrix.

$$A=\begin{bmatrix} a_{11}w_1 & a_{12}w_2 & a_{13}w_3 & a_{14}w_4 \\ a_{21}w_1 & a_{22}w_2 & a_{23}w_3 & a_{24}w_4 \\ a_{31}w_1 & a_{32}w_2 & a_{33}w_3 & a_{34}w_4 \\ \vdots & \vdots & \vdots & \vdots \\ a_{401,1}w_1 & a_{401,2}w_2 & a_{401,3}w_3 & a_{401,4}w_4 \\ a_{402,1}w_1 & a_{402,2}w_2 & a_{402,3}w_3 & a_{402,4}w_4 \end{bmatrix} \tag{15}$$

After that, the problem is solved by TOPSIS method, and the solution steps are as follows.

Define the maximum value Z^+.

$$\begin{aligned} Z^+ &= (Z_1^+, Z_2^+, Z_3^+, Z_4^+) \\ &= (\max\{z_{11}, z_{12}, \cdots, z_{402,1}\}, \cdots, \max\{z_{14}, z_{24}, \cdots, z_{402,4}\}) \end{aligned} \tag{16}$$

Define the minimum value Z^-.

$$\begin{aligned} Z^- &= (Z_1^-, Z_2^-, Z_3^-, Z_4^-) \\ &= (\min\{z_{11}, z_{21}, \cdots, z_{402,1}\}, \cdots, \min\{z_{14}, z_{24}, \cdots, z_{402,4}\}) \end{aligned} \tag{17}$$

We can get.

$$\begin{aligned} Z^+ &= (0.03768342, 0.019346934, 0.004225, 0.000964) \\ Z^- &= (0.00000084937, 0.00000127203, 0.000000123, 0.000607) \end{aligned} \tag{18}$$

Step 2: Calculate the optimal and inferior distances

Define the distance between the $i(i=1,2,\cdots,10)$ th evaluation object and the maximum value D_i^+.

$$D_i^+ = \sqrt{\sum_{j=1}^{2} (Z_j^+ - z_{ij})^2} \tag{19}$$

Define the distance between the $i(i=1,2,\cdots,10)$ th evaluation object and the minimum value D_i^-.

$$D_i^- = \sqrt{\sum_{j=1}^{2} (Z_j^- - z_{ij})^2} \tag{20}$$

In summary, we can get the advantage and disadvantage distance.

Step 3: Calculate the scores of each evaluation object and normalize them to get the final score.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{21}$$

C takes the value of (0,1), the closer to 1, the closer the evaluation object is to the optimal level, the higher the overall score. The scores of each supplier are shown in Table 4 below.

Table 4: The 50 most important suppliers

Supplier ID	Score	Classification	Supplier ID	Score	Classification
S367	0.718173380	B	S131	0.103477338	B
S365	0.657251498	C	S123	0.090982206	A
S364	0.566429680	B	S108	0.086636673	B
S374	0.470238265	C	S080	0.085269587	C
S356	0.449223395	C	S007	0.083178045	A
S352	0.360876436	A	S003	0.080967123	C
S346	0.307362109	B	S005	0.078764012	A
S340	0.299135768	B	S397	0.076103786	B
S329	0.296486871	A	S395	0.074207835	A
S040	0.281282912	B	S392	0.072932640	B
S361	0.263775861	C	S386	0.072640362	B
S282	0.245564837	A	S384	0.067335023	C
S275	0.236339172	A	S383	0.067230040	C
S229	0.207359806	A	S381	0.066811091	A
S306	0.200236821	C	S379	0.066710683	C
S294	0.184559235	C	S377	0.066505140	C
S284	0.182552320	C	S360	0.066271992	B
S268	0.182472376	C	S357	0.064243699	C
S244	0.149855200	C	S336	0.063917743	A
S031	0.136181209	B	S324	0.063611802	B
S247	0.130227068	C	S318	0.061101427	A
S229	0.127675277	A	S310	0.059646928	B
S218	0.120586316	C	S271	0.059602846	C
S194	0.119361866	C	S110	0.057599619	C
S189	0.109536578	A	S076	0.056295380	C

3.3 Results and Analysis

We will test the plausibility of the scoring results. From the perspective of the enterprise, the selected suppliers should ensure the following requirements in order to satisfy the enterprise: the supplier can receive more orders from the enterprise, complete the order of the enterprise accurately[5], and have the ability to supply stable supply. Therefore, we randomly select 2 suppliers for testing and analysis, and the supplier numbers are No. 352 and No. 201 respectively.

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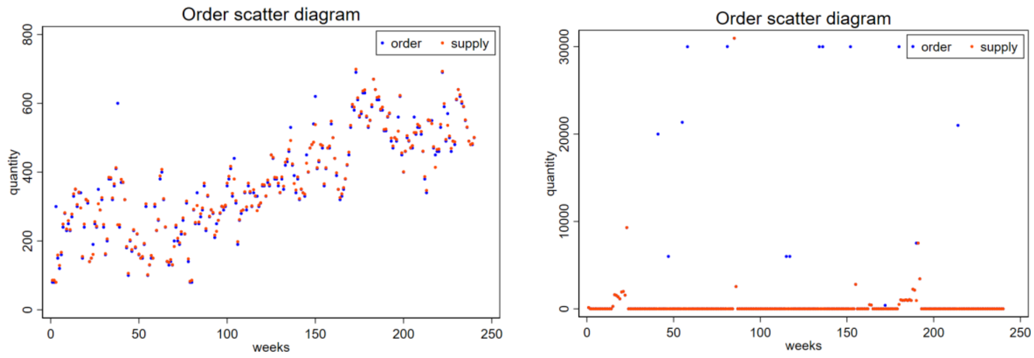

Figure 2: Scatter plot of order quantity supplied by two suppliers

We draw a scatter diagram of the supply volume and the number of orders received by these two companies as shown in Figure 2. We found that supplier No. 352 can receive orders from enterprises every week, and this supplier can the figure shows that with the increase of the number of weeks, the order quantity and shipment volume are also increasing. It can be seen that the overall performance of this supplier is relatively good; on the other hand, supplier No. 201, when an enterprise orders from this supplier Although the weekly order volume is considerable, the raw materials given by the supplier to the company are seriously insufficient, and the number of weeks the company orders during the 240-week period is also significantly too small, so we can think that the supplier has poor performance[6]; then the 352th of the above two suppliers The supplier should be among the 50 high-quality suppliers given by us, but the supplier No. 201 should not be among them. After comparing Table 4, it can be seen that only No. 352 of the two suppliers is among them and the ranking is relatively high. The model solves the results are as expected.

4. Conclusion

This paper quantitatively analyzes the supply characteristics of 402 suppliers, establishes a mathematical model that can reflect the production of enterprises, and determines the 50 most important suppliers. Among them, combining data to analyze the selection of indicators and cleverly selecting the indicator of supplier attractiveness is an innovation to solve this problem; when calculating the weight, two methods are used to average the final weight, which makes the indicator weight more Reasonable. However, other subtle factors that measure supply characteristics may be overlooked in the selection of indicators.

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