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Optimization of Supplier Selection Model based on Game Theory Integrated Empowerment Method

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Abstract

This paper examines the ordering and forwarding of raw materials for a company that produces architectural and decorative panels. By using data and information from various suppliers and forwarders, the analysis of their relevant indicators is used to develop the selection of suppliers that meet the target needs of the company. In this paper, first of all, the supply characteristics of 402 suppliers are quantified and analyzed, and through the attached data, this paper finally finalizes the total number of supplies, total supply, supply order characteristic energy spectrum density and characteristic spectrum as the supplier's supply characteristic index. Then TOPSIS, entropy method and Parseval's theorem are used to assign weights to the first three characteristic indicators, and then the comprehensive weight is determined as the score of each enterprise through the game theory comprehensive assignment method. Finally, this paper selects the most important 50 suppliers based on the final score, and the top three are S201, S140 and S229.

Keywords

Characteristic Index; Spectral Analysis; Game Theory.

1. Restatement of the Problem

A company whose main business is the production of building and decorative panels is producing raw materials such as wood fibers and other vegetal fiber materials, which are roughly divided into three categories, A, B and C, depending on their properties. To ensure the stability of production, the company now needs to identify the most important 50 suppliers to lay the foundation for the healthy development of the company.

2. Development of a Supplier Selection Model based on a Comprehensive Game-theoretic Empowerment Approach

2.1. Construction of Quantitative Index System of Supply Characteristics

2.1.1. Quantitative Indicators and Selection

In order to establish an information structure that effectively describes the supplier's supply characteristics, this question needs to extract the supply characteristics from the supplier's supply records and reflect the supplier's supply capability based on the quantitative analysis of these characteristics. According to the question, this paper defines the supply order characteristics as the difference between the supply quantity and the order quantity, and uses four indicators to measure the supply characteristics: total number of supplies, total supply, supply order characteristics spectrum and energy spectrum density. The structure diagram is shown in Figure 1.

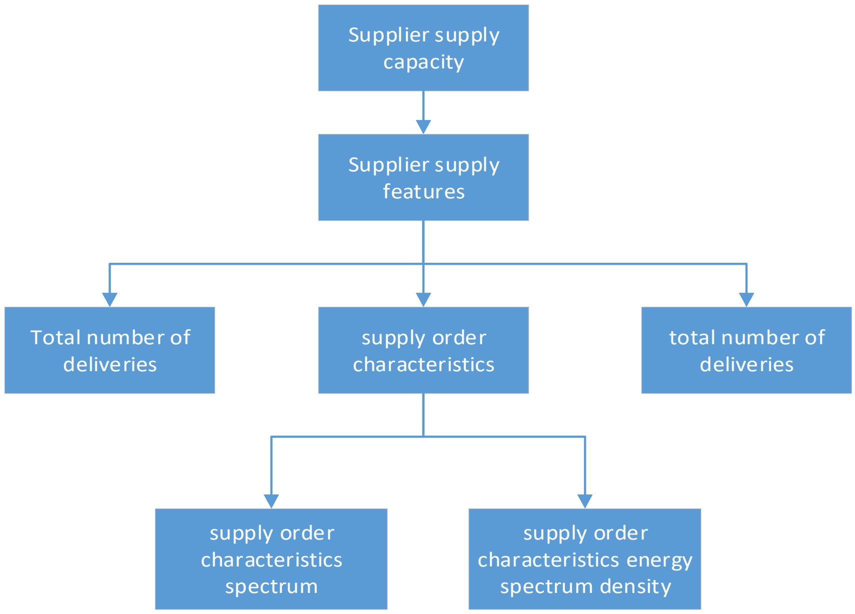

Figure 1. Structure of quantitative indicators of supply characteristics

The definitions of the four indicators and their roles and meanings are summarized in the following table.

Table 1. Definition and role and significance of the four indicators

Indicators	Definition	Role and significance
Total number of deliveries	Number of successful deliveries by the supplier	Reflects supply and demand and supplier importance
Total supply	Total value of supplier's supply	Characterize transaction intensity and importance
Characteristic spectrum	Magnitude spectrum of supply characteristics	Reflecting the regularity of business transactions
Energy Spectral Density	Concentration of power in a certain time period	Reflects the stability of the supply and demand relationship between the company and this supplier

2.1.2. Quantitative Analysis of Supply Characteristics

Regarding the total number of deliveries and the total number of deliveries, the supply order characteristics energy, the data in Annex 1 are processed to obtain the following table.

Table 2. Total number of deliveries, total deliveries and supply order characteristics energy (partial)

Supplier ID	Total number of deliveries	Total supply	Supply order characteristics energy
S001	25	49	5128
S002	71	273	3928
S003	191	13138	543005
S004	33	64	56915
S005	107	6912	3384
S006	13	30	40048
S007	240	6948	89316

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With regard to the spectrum of supply order characteristics, a typical case was selected for analysis. Where the horizontal coordinate represents frequency/f and the vertical coordinate represents amplitude frequency response/S(f).

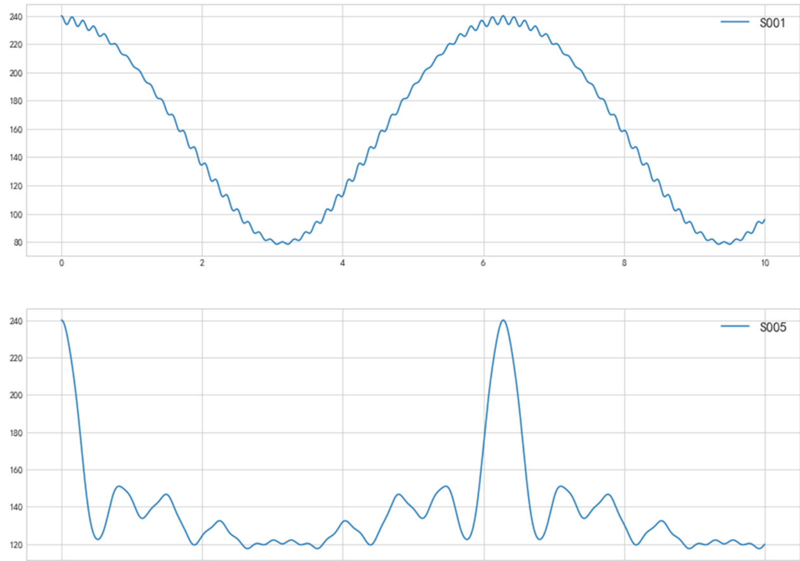

Figure 2. Characteristic spectrum of some suppliers

The above figure is a typical supply spectrum of two, by the nature of the spectrum function can be derived from, S001 as the representative of the supplier's supply trend is fluctuating downward trend, and the greater the degree of trend and fluctuation, reflected in the spectrum of the steeper the valley, the more obvious the teeth; S005 as the representative of the supplier's supply trend in general belongs to the front section of the supply of smooth, the back section of the supply of sudden reduction, and the supply of smooth duration The longer the duration of smooth supply, the wider the bandwidth of the main flap is reflected in the spectrum.

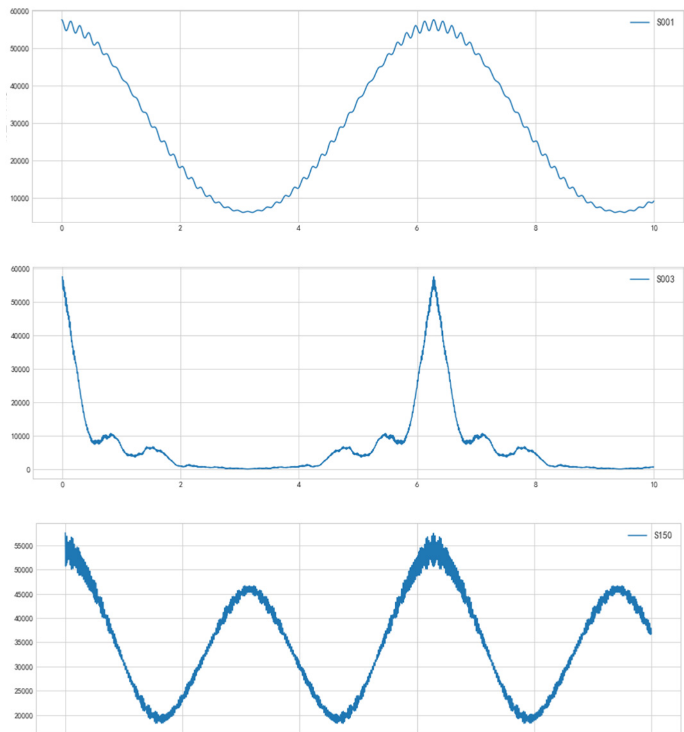

Figure 3. Energy spectrum density of some suppliers

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The supply order characteristic spectrum in this paper is only for descriptive analysis, not as a statistical analysis of indicators.

For the supply order characteristic energy spectral density, we have selected a typical case picture for reference. Where the horizontal coordinate represents the frequency/f and the vertical coordinate represents the energy spectral density.

The above figure shows three typical supply energy spectra, and the nature of the energy spectral density function can be concluded that the supply trend of suppliers represented by S001 and S003 is similar to the previous article, while the overall trend of suppliers typically represented by S150 becomes a state of repeated fluctuations, and the frequency is significantly higher than that of S001, which is reflected in the energy spectral density diagram as a significant tooth pattern and a slightly smaller phase difference.

2.2. Establishment of Supplier Selection Model

2.2.1. Entropy Method of Assignment

In order to be able to accurately judge the orderliness and the utility of information in an information system, we can process information entropy for negative directionalization to obtain information. Therefore, for a determined evaluation system, the information entropy of an indicator is positively correlated with the value of its information, i.e., the smaller the information entropy of an indicator, the smaller the indicator is given a smaller indicator weight; the larger the information entropy, the larger the indicator weight is given [2].

step1: It may be assumed that the sample distribution has no effect on the model. Let the initial series of each indicator be denoted as x_i, and after the forward normalization process be denoted as y_i

step2: Calculate the weight of the j indicator among the i suppliers p_{ij} and the indicator entropy value H_i

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, 0 \le p_{ij} \le 1 \tag{1}$$

$$H_j = -\frac{1}{lnm} \sum_{i=1}^{m} (p_{ij} \cdot lnp_{ij}), 0 \le H_j \le 1 \tag{2}$$

step3: And the utility of the first j indicator can be measured by the information entropy H_j. The value of information entropy H_j is 1, which means that the distribution of indicators is disordered at this time, and the data of this indicator is not useful for evaluation, so we can find the coefficient of variation $g_j$by calculating the difference between information entropy and 1, and then negativizing the information entropy H_j .

$$g_j = 1 - H_j \tag{3}$$

step4: After obtaining the coefficient of variation, the weight of each indicator can be obtained, that is, the weight of the coefficient of variation of each indicator in the sum of coefficients of variation. The weight of the indicator of j w_{j1} can be expressed as

$$w_{ij} = \frac{g_j}{\sum_{j=1}^{n} g_j} \tag{4}$$

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The core of the entropy weighting method is to use the degree of variation of indicators compared with the standard value. Using the entropy weighting method to assign weights can eliminate the influence of subjectivity on the weighting results, and has objectivity and fairness.

The above is the principle of entropy weighting method. In this paper, the entropy weighting method is applied to determine the respective weights of the above three indicators, and the specific algorithm is shown in the Appendix. In this paper, the three indicators are normalized at the same time, and then multiplied by the corresponding entropy method weights, and then the weighted normalized scores of the three indicators are added together to obtain the total comprehensive evaluation score, and then normalized again to obtain the final score, which is recorded as the weight sought by the entropy method. The following table is shown.

Table 3. Entropy method assignment weights (partial)

Supplier number	Weights
S001	0.000830821
S002	0.00242772
S003	0.006880396
S004	0.001108047
S005	0.003828101
S006	0.0004152
S007	0.008431077

2.2.2. TOPSIS Evaluation Model to Determine the Weights

The basic idea of TOPSIS evaluation model is to rank the proximity of the evaluation object to the idealized target, so it is also called the "distance method of superior and inferior solutions". The smaller the distance, the closer the supplier is to the ideal supplier, i.e., the more the supplier meets the needs of the enterprise [3].

step1: Normalize the data of the three indicators in the forward direction to obtain the original data. Find the maximum and minimum values of each index, respectively, as $z_i^+ (i = 1,2,\ldots,m)$ and $z_i^- (i = 1,2,\ldots,m)$, and form a vector

$$Z^+ = (z_1^+, z_2^+, \ldots, z_m^+) \tag{5}$$

$$Z^- = (z_1^+, z_2^+, \ldots, z_m^+) \tag{6}$$

step2: The distance between the i index data and the maximum and minimum values are recorded as

$$D_i^+ = \sqrt{\sum_{j=1}^{m} (z_j^+ - z_{ij})^2} \tag{7}$$

$$D_i^- = \sqrt{\sum_{j=1}^{m} (z_j^- - z_{ij})^2} \tag{8}$$

step3: Let the score of the i supplier be S_j , which is calculated as

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{9}$$

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It is clear that S_j is located between [0, 1]. When is closer to 1, it means that the closer the supplier i is to the ideal supplier, the higher the supplier's ability to supply? Conversely, when is closer to 0, it means that the closer the supplier i is to the non-idealized target, the worse the supplier's ability to deliver.

The supply records of 402 suppliers were substituted into the calculation, and the final table of weights was obtained as follows.

Table 4. TOPSIS evaluation method weights (partial)

Supplier number	Weights
S001	0.000730982
S002	0.002132752
S003	0.005859226
S004	0.000974759
S005	0.00326425
S006	0.000365318
S007	0.007297991

2.2.3. Total Energy Normalization of the Feature Spectrum to Determine the Weights

From Parseval's theorem, it follows that

$$E = \int_{-\infty}^{\infty} S^2(t)dt = \int_{-\infty}^{\infty} |S(f)|^2 df \tag{10}$$

The above equation indicates that the integral of the supply order characteristic energy spectral density on the frequency axis f is the supply order characteristic energy, which is not repeated here because the supply order characteristic energy has been found in the previous section. The supply characteristic energy is normalized and used as the weight of the supplier; part of the table is as follows.

Table 5. Feature energy normalized weights (partial)

Supplier number	Weights
S001	0.00000075
S002	0.00000057
S003	0.00007963
S004	0.00000835
S005	0.00000050
S006	0.00000587
S007	0.00001310

2.2.4. Game Theory Integrated Empowerment Method

The game theory integrated assignment method is a method to obtain the equilibrium weights by linearly combining all the weights. The principle is to use multiple assignment methods to find the weights and combine them into a weight vector group, and use the basis vectors in the weight vector group to solve the optimal vector group as the optimal weights. The use of game theory model greatly enhances the rationality and scientific of the assignment [1].

step1: In this paper, three different weight regrouping methods have been used to derive three different weight regrouping. Namely $w_k = (w_{k1}, w_{k2}, \ldots, w_{km}), k = 1,2,3.$ the two weight regroups are used to construct a basis vector group of the vector space.

$$w = (w_1, w_2, w_3) \tag{11}$$

Naturally the full vector space consists of any combination of the weight vectors in w.

$$\mathrm{w} = \sum_{\mathrm{k}=1}^{3} \mathrm{a_k w_k^T} (\mathrm{a_k} > 0) \tag{12}$$

In the above equation a_k is the weight coefficient, and is the set of vectors formed by linear combinations of basis vectors w.

step2: In order to determine the optimal set of vectors w^*, the divergence of the set of vectors from each ω_k must satisfy the minimization.

$$\min || \sum_{\mathrm{k}=1}^{3} \mathrm{a_j w_j^T} ||_2 (\mathrm{i} = 1,2,3) \tag{13}$$

Differentiating the matrix, it is not difficult to find the optimal solution form of the above equation, i.e.

$$\sum_{\mathrm{k}=1}^{3} \mathrm{a_j w_i w_j^T} = \mathrm{w_i w_j^T} (\mathrm{i} = 1,2,3) \tag{14}$$

Corresponding linear system of equations.

$$\begin{bmatrix} w_1 \cdot w_1^T & w_1 \cdot w_2^T & w_1 \cdot w_3^T \\ w_2 \cdot w_1^T & w_2 \cdot w_2^T & w_2 \cdot w_3^T \\ w_3 \cdot w_1^T & w_3 \cdot w_2^T & w_3 \cdot w_3^T \end{bmatrix} \begin{bmatrix} a_1 \\ a_1 \\ a_1 \end{bmatrix} = \begin{bmatrix} w_1 \cdot w_1^T \\ w_2 \cdot w_2^T \\ w_3 \cdot w_3^T \end{bmatrix} \tag{15}$$

Solve for the weighting factors and normalize the scaling factors to.

$$\mathrm{a}^* = \frac{\mathrm{a_k}}{\sum_{\mathrm{k}=1}^{3} \mathrm{a_k}} \tag{16}$$

step3: Finalize the combination weights.

$$\mathrm{w}^* = \sum_{\mathrm{k}=1}^{3} \mathrm{a}^* \mathrm{w_k^T} = \mathrm{w_i w_j^T} \tag{17}$$

The weights obtained by the entropy method, TOPSIS evaluation method, and characteristic energy normalization method used in the previous section were substituted into the game theory integrated assignment model to obtain the integrated weights as shown in the following table.

Table 6. Game theory integrated empowerment results (partial)

Supplier number	Combined weights
S001	0.000703244
S002	0.002051197
S003	0.005646367
S004	0.00093766
S005	0.003145071
S006	0.000351621
S007	0.007020708

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Using the game theory comprehensive weighting model to obtain the weight of 402 suppliers, that is, the size of the impact of the supplier on the enterprise's order supply, that is, the comprehensive weight of the supplier to ensure that the enterprise's production continuity role is greater, and vice versa.

2.2.5. Solving the Supplier Selection Model

As can be seen from the foregoing, the production enterprise to choose suppliers, only need to give priority to the production and supply of this enterprise impact of the supplier, that is, the comprehensive weight of the top 50 in descending order, the list is as follows.

Table 7. 50 most important suppliers

Ranking	Number	Ranking	Number	Ranking	Number	Ranking	Number
1	S201	14	S330	27	S365	40	S294
2	S140	15	S131	28	S031	41	S244
3	S229	16	S356	29	S395	42	S218
4	S361	17	S268	30	S040	43	S314
5	S108	18	S126	31	S364	44	S114
6	S151	19	S306	32	S150	45	S291
7	S348	20	S194	33	S367	46	S338
8	S340	21	S352	34	S123	47	S098
9	S282	22	S143	35	S266	48	S086
10	S275	23	S307	36	S055	49	S076
11	S329	24	S247	37	S346	50	S037
12	S139	25	S374	38	S007		
13	S308	26	S284	39	S080		

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