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Research on Ordering and Transportation of Raw Materials in Manufacturing Enterprises Based on TOPSIS Model

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Abstract: *In real life, the selection of raw material suppliers is very important for production enterprises. This paper mainly studies the optimal ordering and operation scheme to ensure the production of enterprises. In order to quantify the supply characteristics, emphasize the guarantee of enterprise products and make decisions on suppliers, this paper selects five indicators, such as supply risk, supply intensity, supply fluctuation, supply operation capacity and order cost. Then, this paper uses the analytic hierarchy process and entropy weight method to subjectively weight and objectively weight the five indicators, respectively, and couples the subjective and objective weights according to the Lagrange multiplier method to solve the optimal comprehensive weight. Finally, the total weight is brought into the TOPSIS model. The TOPSIS Model under the combined weight of analytic hierarchy process and entropy weight method is established to solve the final result.*

Keywords: *TOPSIS model, Analytic hierarchy process, Entropy weight method*

1. Introduction

In actual production and life, the production enterprises operating building and decorative plates need three types of wood fiber and other plant fiber raw materials A, B and C in the process of arranging production, and the production time is 48 weeks. The enterprise needs to select suppliers in advance according to the actual production capacity requirements of the enterprise, determine the weekly order quantity of class A, B and C raw materials and the forwarder to help the enterprise transport goods, and formulate the supplier's stable supply and the safe transfer plan of the forwarder in the next 24 weeks. In order to ensure the stability and security of the supply system, suppliers and forwarders need to be related one by one as far as possible.

2. TOPSIS Model under the combined weight of analytic hierarchy process entropy weight method

2.1 Model analysis

In question 1, it is required to conduct a quantitative analysis on the supply characteristics of suppliers according to the data in Annex 1, establish a mathematical model reflecting the importance of ensuring the production of enterprises and determine 50 important suppliers. Firstly, problem 1 can be classified as "evaluation + decision-making" problems. Then, the data in Annex I are processed accordingly, and the evaluation indicators reflecting the importance of ensuring enterprise production are selected. When weighting the selected evaluation indicators, to reduce their subjectivity, the total weight of this topic adopts emotional weight and objective weight to improve the combination weight through coupling. It is known that the analytic hierarchy process is a typical subjective weighting method. The entropy weight method is a conventional objective weighting method. Therefore, the different advantages of the two methods can be used to couple the calculated subjective and objective evaluation index weights through the Lagrange multiplier method to synthesize the optimal weights. In order to determine 50 important suppliers, it is also necessary to establish a decision model according to the evaluation index so that the importance of suppliers can be ranked based on the importance of ensuring the production of enterprises. TOPSIS method is a common and effective method in multi-objective decision analysis and a ranking method close to the ideal solution. Therefore, this topic finally improves the existing methods. Finally, the TOPSIS Model is established under the combined weight of the analytic hierarchy process entropy weight method, and 50 important suppliers are solved.

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2.2 Model establishment

In question 1, it is required to conduct a quantitative analysis on the supply characteristics of suppliers according to the data in Annex 1, establish a mathematical model reflecting the importance of ensuring the production of enterprises and determine 50 important suppliers.

(1) Selection of evaluation indicators

According to the actual situation [1] of the production and operation of the building and decorative plate manufacturers and the relevant literature on enterprise operation consulted, combined with the principles determined by the evaluation index system, and from the perspective of enterprises and suppliers, the supplier evaluation indexes [1] reflecting the importance of ensuring enterprise production are established, namely supply risk, supply intensity, supply operation strength, supply fluctuation five indicators such as ordering cost.

Indicator 1: supply risk (R)

Because this type of raw materials is special, suppliers may not always meet the order proportion, and the actual supply may be more or less than the order quantity. And enterprises may face major risks such as stopping production due to insufficient supply. Therefore, supply risk can be used as an index to evaluate the importance of suppliers.

There are multiple groups of data with an order quantity of 0 in the original data. When considering the supply risk index, the data with an order quantity of 0 does not reference. Therefore, it can directly delete the order quantity data and supply quantity data with an order quantity of 0. Secondly, the sample data is statistically processed according to whether the supplier meets the ordering proportion, that is:

(a) When the order quantity of the enterprise is greater than the supply quantity, the data d_{ij} of the current week is recorded as $\frac{x_j-y_j}{x_j}$ to reflect the shortage degree of the enterprise, where i is the specific supplier, the range is$i \in [1,402]$, j is the specific number of weeks, and the range is $j \in [1,240]$;

(b) When the enterprise's order quantity is less than the supply quantity, the data d_{ij} of the current week is recorded as 1.

See formula (1) for details,

$$d_{ij} = \begin{cases} \frac{x_j-y_j}{x_j}, & x_j \geq y_j \\ 1, & x_j < y_j \end{cases} \tag{1}$$

Where j is the specific number of weeks, i is the specific supplier, the weekly order quantity of the enterprise is recorded as x_j, the weekly supply quantity of the supplier is recorded as y_j, and d_{ij} is the data of week j after processing the sample data.

Count the effective columns, i.e. effective weeks, of the processed data, and record it as Si, where i represents the specific supplier, and its value range is [1, 402]. If the supply risk index is recorded as R, the risk index is recorded as R, which can be quantified as:

$$\mathrm{R} = 1 - \frac{\sum_{j=1}^{s_i} d_{ij}}{s_i} \tag{2}$$

Where j is the specific number of weeks, the range is j $\in$ [1, 240], and I represents the specific supplier, and its value range is i$\in$[1, 402]. Among them, $\frac{\sum_{j=1}^{s_i} d_{ij}}{s_i}$ can reflect the ordering satisfaction, and the value is between [0,1]. If the value tends to 1, it indicates that the higher the ordering satisfaction of the enterprise, the lower the supply risk of the supplier; Similarly, if the value tends to 0, it indicates that the lower the order satisfaction of the enterprise, the higher the supply risk. Therefore, the risk index can be quantified by formula (2).

Index 2: supply intensity (S)

Supply intensity refers to the number of raw materials provided by the supplier, which can be used to reflect the supply strength of the supplier. Therefore, supply intensity can be used as an index to evaluate the importance of the supplier. The supply intensity index is recorded as S. Analyze the supply volume of suppliers: the data of 402 suppliers in recent 5 years can be summed as the supply intensity index, and

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the data of week J of the ith supplier of the original data of suppliers can be recorded asD_{ij}. Where i represents the specific supplier, and j represents the specific number of weeks, the supply intensity index can be expressed as:

$$S=\sum_{i=1}^{240} D_{ij} \tag{3}$$

Where i represents a specific supplier, its value range is [1, 402], and j represents a specific number of weeks, and its value range is i∈[1, 240]. The greater the value of S, the more the supplier has supplied in recent years, the stronger the corresponding supply capacity, and the more it can reflect the needs of ensuring the normal production of the enterprise. Therefore, the risk index can be quantified by formula (3).

Indicator 3: supply and operation strength (a)

Supply and operation strength is an important index to evaluate whether the supplier can cooperate with the supplier for a long time, which is very important to the normal production of the enterprise. Therefore, it can be used as an evaluation index to reflect and ensure the normal production of the enterprise. Process and analyze the supplier's supply quantity data:

$$D_{ij}=\begin{cases}0, & D_{ij}=0\\ 1, & D_{ij}\neq 0\end{cases} \tag{4}$$

Where i represents the specific supplier, its value range is [1,402], j represents the specific number of weeks, and its value range is [1, 240]. The final D_{ij} is the data of week J of the ith supplier after the original data is processed by equation (4). Then sum up the weekly supply quantity of each supplier after processing as the quantitative index of supply operation strength, which is recorded as A, then

$$A=\sum_{i=1}^{240} D_{ij} \tag{5}$$

D_{ij} in equation (5) is different from equation (3). D_{ij} in equation (3) is the original data, and D_{ij} in equation (5) is the data processed according to equation (4). The greater the value of A, the more goods the supplier supplies. Then A can be used as an indicator to evaluate the importance of the supplier.

Indicator 4: supply fluctuation(σ)

Supply fluctuation is used to measure the stability of suppliers' supply. Here, the physical quantity of mean square deviation is used to quantify the supply fluctuation index. Record the supply fluctuation index as σ , Then the supply fluctuation index can be expressed by formula (6), i.e

$$\sigma=\sqrt{\frac{\sum_{j=i}^{240}\left(D_{ij}-\overline{D_{\iota J}}\right)^2}{240}} \tag{6}$$

Where j is the specific number of weeks, j is the specific supplier, and D_{ij} is the supply volume of a specific supplier in a specific week. σ the larger the value, the more unstable the supplier's supply is. Similarly, it can be obtained σ the smaller the value is, the more stable the supplier's supply is, so the normal production of the enterprise can be guaranteed.

Indicator 5: ordering cost (P) [3]

It is known that there are three types of raw materials in the enterprise: A, B and C, which correspond to the suppliers providing class A, B and C raw materials, respectively. Based on the ordering data of the enterprise, it can be seen that the enterprise should consider the types of raw materials in order. The purchase unit price of class raw materials is the highest, which is 1.2 times that of class C, and class B is 1.1 times that of class C; In terms of raw materials consumed in the production of products, 0.6m3 of class raw materials, 0.66m3 of class B raw materials, or 0.72m3 of class C raw materials are consumed per cubic meter of products. Therefore, we can start from the category of raw materials. First, we can calculate the total order quantity of 240 weeks from the original order quantity data and then determine the weight of class A, B and C raw materials according to the purchase unit price of different raw materials and the consumption of different raw materials per cubic meter of product. Let PA, PB and PC

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represent the purchase unit price of class A, B and C raw materials, SAi and SBi respectively, SCi respectively represents the total supply volume of each supplier in recent five years, MA, MB, and MC represent the weight of three raw materials A, B and C, and the weight calculation formula is:

$$m_k = \mathrm{T_k} \times P_k \ (k = A, B, C) \tag{7}$$

Where TK is the number of raw materials a, B and C consumed per cubic meter of product, and its values are TA=0.6, TB=0.66 and TC=0.72. The practical significance of the weight of three types of raw materials is the cost of the class of raw materials required to produce products per cubic meter. Then, the weight of three types of raw materials is multiplied by the corresponding total supply to quantify the ordering cost index. That is, the ordering cost P is

$$P = m_k \times S_{k_i} \ (k = A, B, C) \tag{8}$$

Where m_k represents the weight of class A, B and C raw materials, i represents the specific supplier, and S_{k_i} represents the total order quantity of 3 class raw materials. When the ordering cost index P is larger, the enterprise has less profit without considering the rise of product price. On the contrary, when the ordering cost index P is smaller, the enterprise has more profit, ensuring the normal production and operation of the enterprise. Therefore, the ordering cost can be regarded as the evaluation index of the importance of suppliers to ensure production.

(2) Solving subjective weight by analytic hierarchy process

The previously selected supplier importance evaluation index is based on reflecting and ensuring enterprise production is based on real-life experience and literature review. Therefore, the selection of indicators has been subjective and objective. Therefore, the five evaluation indexes should be weighted in a combination of subjective and objective. The analytic hierarchy process is a typical subjective evaluation method. Using the analytic hierarchy process model to determine the weight is divided into four steps: establishing hierarchical structure model, constructing judgment (pairwise comparison) matrix, calculating characteristic root, hierarchical total ranking and consistency test.

STEP1 Establish a hierarchical model

STEP2 Construct judgment (pairwise comparison) matrix

STEP3 Calculate the characteristic root

STEP4 Consistency test.

(3) Solving subjective weight by analytic hierarchy process

The entropy weight method determines the objective weight according to the size of index variation information. The more volatile the data, the greater the index variability.

• If 5 evaluation indexes and 402 evaluation objects are known, the original data matrix is formed: $R = (P_{ij})$.

• The data table is transformed, and each index is dimensioned: $y_{ij} = \frac{\mathrm{P_{ij}}-5}{M-5}$.

• Calculate the entropy Ei of each index, then: $E_j = -\frac{1}{\ln 402}\sum_{i=i}^{5} C_{ij} \ln C_{ij}$.

• Calculate the difference coefficient $D_j = 1 - E_j$.

•Calculate the weight of each index $\varphi_j = \frac{D_j}{\sum_{j=1}^{5} D_j}$.

(4) Coupling calculation of analytic hierarchy process entropy weight method: Based on Lagrange multiplier method

The Lagrange multiplier method is a method to find the extreme value of a multivariate function whose variable is limited by one or more conditions. This method is selected for coupling in this problem. The formula is as follows:

$$P\varphi_t = \frac{\sqrt{\varphi_{1t}\varphi_{2t}}}{\sum_{t=1}^{s}\sqrt{\varphi_{1t}\varphi_{2t}}} \tag{9}$$

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(5) Application of analytic hierarchy process entropy weight method in TOPSIS.

TOPSIS Model [5] is a commonly used and effective method in multi-objective decision analysis. It is a ranking method close to the ideal solution. Its core is a multi-dimensional comprehensive evaluation model. This topic uses the TOPSIS model combined with the optimal weight coupled with the analytic hierarchy process entropy weight method to make decision ranking based on the importance of suppliers to ensure enterprise production.

• Construct the evaluation matrix A of sample data and standardize it.

• Combined with the weight obtained by the above analytic hierarchy process entropy weight method, the evaluation matrix A of sample data is multiplied by the evaluation matrix A to obtain the value matrix v

• Determine the positive and negative ideal solutions, combine the maximum value of the very large index and the minimum value of the very small index to form the positive ideal solution, and combine the maximum value of the very small index and the very large index to form the set of negative ideal solutions.

• Calculate the Euclidean distance between each scheme and the positive and negative ideal solution [6]

• Calculate the relative closeness of each party to the ideal solution

• The schemes are sorted according to the size of ci. The larger the ci, the better the evaluated object is, and the value range of ci is [0,1]

So far, the TOPSIS multi-attribute decision-making scheme under the combined weight of analytic hierarchy process entropy weight method approaching the ideal point has been constructed.

2.3 Model solving

STEP1 Quantitative solution of five evaluation indexes

This paper tries to analyze and solve the specific indicators, use the order and supply quantity for preliminary statistical preprocessing, and then use Matlab programming to realize the quantitative processing of five evaluation indicators.

STEP2 Calculating the subjective weight of indicators by analytic hierarchy process

Using MATLAB to write a program to calculate the emotional weight by analytic hierarchy process, and based on the paired comparison matrix solved by santy's $1-9$, the tested coefficient Cr is $0.0547 < 0.1$, which passes the consistency test.

STEP 3 Solving objective matrix by entropy weight method

The weight of entropy weight method is solved by writing the Matlab program.

STEP 4 Coupling calculation of analytic hierarchy process entropy weight method: Based on Lagrange multiplier method.

According to the literature, the Lagrange multiplier method is the most time to couple the subjective and objective weights here, which can be realized by programming with MATLAB.

STEP 5 Decision making of supplier importance based on TOPSIS Model with combined weight based on analytic hierarchy process entropy weight method

Using MATLAB programming, by solving the relative closeness Ci of each scheme to the ideal solution, the schemes are sorted according to the size of CI. The final result of the solution, that is, the most important 5 suppliers, is 229, 361, 140, 108, 151.

3. Model Evaluation

The TOPSIS Model under the combined weight of analytic hierarchy process entropy weight method is established. The selected evaluation indexes are given subjective and objective weights, respectively, combined with the actual production situation and literature. Then the Lagrange multiplier method is used to couple the subjective and objective weight to solve the total weight. By improving the existing models and combining the advantages of each model, a comprehensive evaluation and decision-making

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model is established, which has good applicability and ductility, small error and high reliability

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