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Optimal Vendor Selection Model based on TOPSOIS and Analytic Hierarchy Process

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Abstract

The problem of raw material ordering is the key to solve how to guarantee the safe production of enterprises. We determine six kinds of quantitative indicators to represent supply and demand relationship, namely, supply stability parameter, satisfied supply rate, supply quantity, average supply error, flexible supply index, average supply ratio. Based on this, we establish the quantized original matrix of supply and demand characteristics. In order to identify the most important suppliers, we established a weighted TOPSIS model to evaluate 402 suppliers. In the process of determining the weight vector, we introduced the analytic hierarchy process, and obtained the judgment matrix through expert scoring, and finally obtained the weight vector of the six indicators: [0.04545455, 0.22727273, 0.36363636, 0.09090909, 0.13636364, 0.13636364] The weights were input into the model with the original matrix after the forward normalization, and the comprehensive scores of 402 suppliers were obtained. Fifty suppliers were selected which were of great significance to production safety. All the processing is done using Python or MATLAB.

Keywords

Analytic Hierarchy Process; TOPSIS; Quantitative Indicators; Production Safety.

1. Introduction

An enterprise is engaged in the production of building and decorative boards, mainly using wood fiber and other vegetal fiber materials as production raw materials (including A, B, C, but can meet the production requirements). Due to the uncertainty in the supply process, there may be a certain gap between the actual supply and the expected order quantity. Therefore, it is necessary for enterprises to identify a group of most important suppliers from the perspective of production guarantee, and give priority to purchasing raw materials from these suppliers. We hope to build a model that shows the importance of production for the enterprise and quantify the supply characteristics of suppliers, so as to identify the most important suppliers. In this paper, we identify 50 as a cardinal number.

2. Problem Analysis

The problem requires a quantitative analysis of the supply characteristics of 402 suppliers, an analysis of the factors influencing the production of the company, and the selection of the 50 most important suppliers accordingly. To ensure the production of the enterprise involves the supplier's ability to supply, risk factors and stability and other aspects of the impact, we have identified six types of indicators, including the supply satisfaction rate, by mining the data itself, combining the characteristics of supply and demand and literature search, forming the basis for the assessment of the importance of suppliers.

For this kind of evaluation and decision problem under multiple indicators, we choose the TOPSIS model considering weights, firstly, we calculate the original matrix of 6 categories of indicators for 402 suppliers, and then input it into the framework of TOPSIS model, and solve for the weights corresponding to 6 categories of indicators, introduce hierarchical analysis, and the obtained weight vector acts on the calculation of 402 suppliers' scores. Finally, the top 50 suppliers are selected as the most important suppliers according to the ranking of the scores. The quantitative analysis of the supply characteristics and the selection of important targets are completed. Our working process is shown in Figure 1.

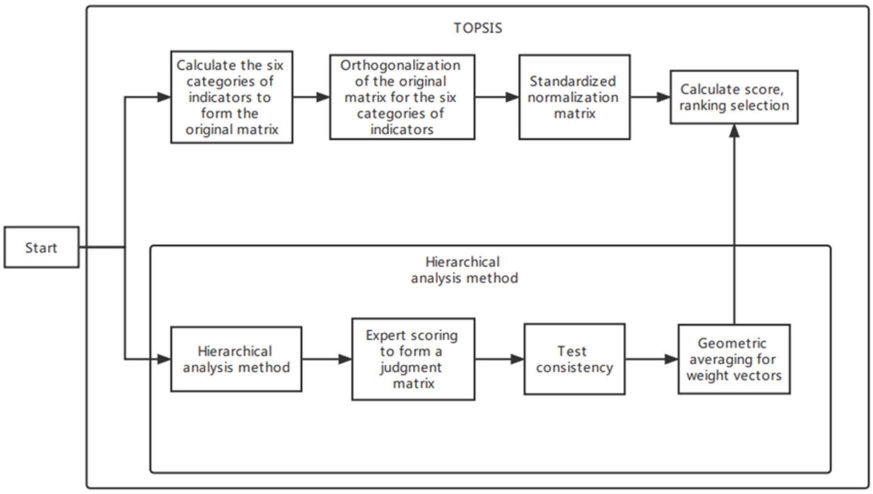

Fig 1. Working process

3. Organization of the Text

3.1. Determination of Quantitative Analysis System of Supply Characteristics

This question has the characteristics of a typical evaluation and decision problem. Through the study of related papers and further mining of the data in Annex 1, we initially identified six evaluation indicators to measure the characteristics of supply: meeting the supply rate, supply quantity, etc. We quantified the indicators and analyzed them one by one.

(1) Satisfied supply rate, in the case of a certain amount of supply requests sent to the supplier by the enterprise (i.e., the order quantity is not zero), the proportion of the number of times the actual supply quantity from the supplier is greater than or equal to the order quantity. Let D1 be the number of weeks to meet the order schedule, then the rate of fulfilled deliveries k is expressed as follows: $K_1 = \frac{D_1}{240}$. The value actually reflects the probability of the supplier to meet the order demand, in a sense, reflects the level of credibility of the supplier and the risk of supply, which is important for the normal production operation of the enterprise, and to a certain extent, directly determines the choice of suppliers for the enterprise.

(2) Supply volume. Some of the larger suppliers are usually able to provide large quantities of raw materials for a single order, greatly reducing the pressure on the company to develop an ordering strategy, while also being able to meet the excess supply required for some special situations. In other words, such suppliers with the ability to respond to large-scale orders are essential pillars for the survival and growth of a business. We may consider that in most cases, meet the supply rate can only show the relative ratio, suppose we compare two different suppliers, the enterprise for the first order quantity of 100 and for the second order quantity of 1, the two final actual supply quantity have reached the predetermined standard (i.e., supply

quantity / order quantity ≥ 100%), at this time if the two suppliers directly to choose, obviously will be more inclined to the former. This is due to the fact that suppliers who can meet large order volumes have a greater potential to address unexpected demand for production materials, etc.

(3) Continuity and stability of supply. This is a cross-sectional comparison of the stability of each supplier's supply capacity. Consider the enterprise for a supplier A order quantity to maintain a relatively stable situation, we observe A in a longer time scale of the actual supply. Let the supply vector of a supplier for 240 weeks be X. We refer to the percentage measure to construct the indicator:

$$S = \frac{X_{\max} - X_{\min}}{X_{mean}} \tag{1}$$

The smaller the S, the smaller the fluctuation of the supplier's supply within 240 weeks, which reflects the stability of a supplier's supply over a period of time, and also becomes an important indicator for the selection of enterprises.

(4) Average supply error. In a certain period of time, for a certain supplier, consider the absolute value of the accumulated sum of the error of its each supply and the predetermined amount corresponding to that supply, and let the supplier receive the order quantity R and the actual supply quantity G. The average supply error is expressed as:

$$LOSS = \frac{1}{240}\sum_{i=1}^{240}\left|R_i - G_i\right| \tag{2}$$

If the average error is large, it is reasonable to assume that the supplier's ability to supply on demand is weak, and the company needs to leave some margin for its single supply expectations to avoid the occurrence of undersupply or warehouse piling.

(5) "Supply flexibility Index". We think the supplier's supply can be divided into several intervals, each interval marks a scale business of supply, for each of the different suppliers, its availability is different, the distribution range of span is different also, we try to find some suppliers, has a wide business scope to accept orders in a larger range, can adapt to the different needs of enterprises in different periods. We explore the distribution of non-zero supply quantity of all suppliers and divide seven supply quantity intervals with each octant boundary. The value of this index is represented by the number of all supply quantity situations of a supplier belonging to the above interval.

(6) The "average supply share", since each producer produces only one raw material, there must be some kind of comparison and competition between manufacturers producing the same raw material, and the average supply share is expressed as:

$$P_j = \frac{G_{ij}}{\sum_{i=1}^{240} G_{ij}} \tag{3}$$

Through a side-by-side comparison, we can get that for the same material, the merchant with stronger supply capacity has a correspondingly larger share of supply in a single week.

3.2. TOPSIS Evaluation Model Construction with Weights

Step1 Evaluation index original matrix establishment

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We obtain six sets of 402-dimensional vectors according to the proposed calculation method of the six measures, and combine the six sets of column vectors to obtain the initial matrix of the TOPSIS model:

Table 1. The initial matrix of the TOPSIS model

Supply stability parameters	Meet the availability rate	Supply quantity	Average delivery error	Supply flexibility index	Average supply percentage
210.6122449	0.208791209	49	0.758333333	5	5.24604E-05
52.74725275	0.673684211	273	0.15	13	0.000193223
8.037753083	0.854271357	13138	4.754166667	106	0.008868602
375	0.203883495	64	2.704166667	6	6.91152E-05
4.861111111	0.903508772	6912	1.558333333	52	0.005344017
800	0.2	30	1.8	5	1.79783E-05
6.597582038	0.866666667	6948	0.966666667	47	0.006197167
58.53658537	0.25	41	0.220833333	6	2.7785E-05
2477.419355	0.15	31	2.85	3	3.36708E-05
141.1764706	0.227272727	170	1.691666667	12	0.000148351
...	...	...	...	...	...
685.7142857	0.054794521	35	3.845833333	5	3.73218E-05

Step2 Standardized normalization matrix

Among the six types of indicators of supply characteristics, the supply stability parameter and the average supply error are significant very small rows (cost-type) indicators, and the remaining indicators are very large (benefit-type) indicators, so we normalize the original matrix as follows.

$X_{ij} = \max(x_j) - x_{ij}$.Among them, X_{ij} denotes the value in row i and column j of the matrix, X_j denotes the data in column j of the matrix. In this paper, we need to perform the above operation on column 0 and column 3 of the original matrix, i.e., the values of j are j=0,j=3 to obtain the orthogonalized matrix.

Step3 normalized normalization matrix

After obtaining the normalized matrix with 402 evaluation objects and m evaluation indicators, we compressed the values in the matrix in the range of [0,1] by calling the data normalization method of the python machine learning library "sklearn" to eliminate the influence of different indicators' scales.

The original matrix is normalized and normalized to obtain the following matrix:

Step4 Construction of weight vector based on hierarchical analysis

Based on the problem analysis, we determined the basic evaluation indicators and influencing factors.

Considering the fact that the final decision result is influenced by a variety of factors, each of which has a different degree of influence on the delivery characteristics and delivery capacity. At the same time, the desired goal of realization shows a tendency for certain indicators. For example, in order to ensure that the company's production can run normally and meet the production capacity as much as possible, the supplier's supply index is bound to occupy a higher weight. Therefore, we use AHP to obtain the weights of each influencing factor.

Building a hierarchical model

We decompose the decision problem into three levels, the top level is the objective level, i.e., the ultimate goal is to guarantee the production of the enterprise; the bottom level is the solution level, which includes 402 suppliers with different supply materials, size and scope of operation; the middle level is the criterion level. Based on the different focus of supplier stability and size and business scope in the criterion layer, the covariance of the corresponding quantitative indexes can be considered small.

Table 2. Matrix of indicators after forwarding and normalization

Supply stability parameters	Meet the availability rate	Supply quantity	Average delivery error	Supply flexibility index	Average supply percentage
0.994188	0.208791	5.92E-05	0.999318	0.017699	0.000136
0.998562	0.673684	0.00069	0.999865	0.053097	0.000655
0.999801	0.854271	0.036944	0.995722	0.464602	0.032642
0.989632	0.203883	0.000101	0.997567	0.022124	0.000198
0.99989	0.903509	0.019399	0.998598	0.225664	0.019647
0.977854	0.2	5.64E-06	0.99838	0.017699	9.34E-06
0.999841	0.866667	0.019501	0.99913	0.20354	0.022792
0.998402	0.25	3.66E-05	0.999801	0.022124	4.55E-05
0.931369	0.15	8.45E-06	0.997435	0.00885	6.72E-05
0.996112	0.227273	0.0004	0.998478	0.048673	0.00049
0.999242	0.651163	0.000161	0.999996	0.026549	0.000169
0.988557	0.147059	2.82E-06	0.998954	0.017699	1.58E-05
0.998815	0.655172	4.51E-05	1	0.017699	5.86E-05
0.999549	0.592593	0	0.999985	0.00885	6.91E-06
…	…	…	…	…	…
0.981021	0.054795	1.97E-05	0.996539	0.017699	8.07E-05

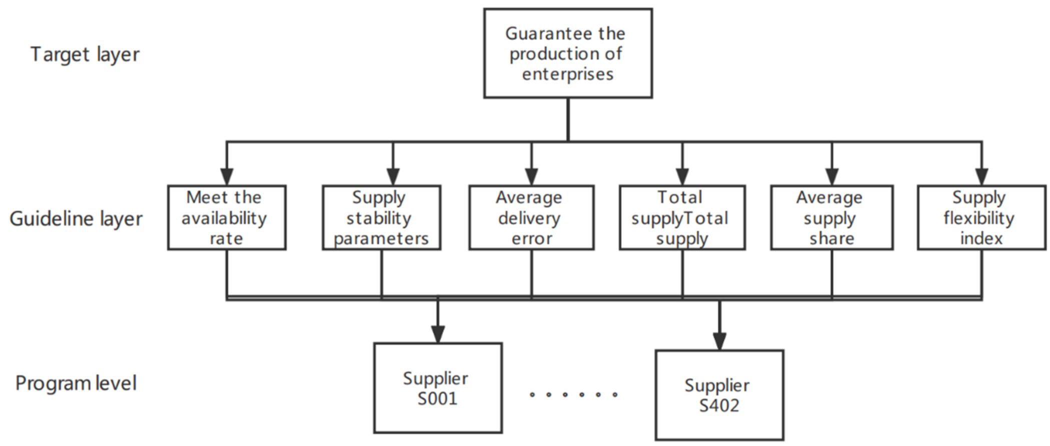

Fig 2. Hierarchy of supplier selection

Obtain the judgment matrix

Expert scoring for the above six categories of indicators yields a judgment matrix:

$$A=\begin{bmatrix} 1 & 5 & 8 & 2 & 3 & 3 \\ \frac{1}{5} & 1 & \frac{8}{5} & \frac{2}{5} & \frac{3}{5} & \frac{3}{5} \\ \frac{1}{8} & \frac{5}{8} & 1 & \frac{1}{4} & \frac{3}{8} & \frac{3}{8} \\ \frac{1}{2} & \frac{5}{2} & 4 & 1 & \frac{3}{2} & \frac{3}{2} \\ \frac{1}{3} & \frac{5}{3} & \frac{8}{3} & \frac{2}{3} & 1 & 1 \\ \frac{1}{3} & \frac{5}{3} & \frac{8}{3} & \frac{2}{3} & 1 & 1 \end{bmatrix}$$

The consistency index CI=0.0 and the consistency ratio CR=0.0<0.1 of this judgment matrix indicated that this judgment matrix passed the consistency test.

Calculate the weight vector

The judgement matrix found above satisfies the following form: $A=\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix}$, the geometric mean method for finding the weight vector is given by

$$\omega_i=\frac{(\prod_{j=1}^{n} a_{ij})^{\frac{1}{n}}}{\sum_{k=1}^{n}(\prod_{j=1}^{n} a_{kj})^{\frac{1}{n}}},\quad (i=1,2,\cdots,n) \tag{4}$$

The results are calculated as [0.04545455, 0.22727273, 0.36363636, 0.09090909, 0.13636364, 0.13636364].

Score calculation and target selection

The obtained weight vectors and the standardized matrix of evaluation indicators are entered into the framework of the TOPSIS model to obtain a comprehensive score for 402 companies. The calculation method is as follows: Let the normalization matrix obtained in the previous step be Z. Then Z satisfies the form: $Z=\begin{pmatrix} z_{11} & \cdots & z_{1m} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nm} \end{pmatrix}$.

we define an optimal vector:

$$\begin{aligned} Z^{+} &= (Z_1^{+}, Z_2^{+}, \cdots, Z_m^{+}) \\ &= (\max\{z_{11}, z_{21}, \cdots z_{n1}\}, \max\{z_{12}, z_{22}, \cdots z_{n2}\}, \cdots, \max\{z_{1m}, z_{2m}, \cdots z_{nm}\}) \end{aligned}$$

and a worst-case vector:

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$$
\begin{aligned}
Z^- &= (Z_1^-, Z_2^-, \cdots, Z_m^-) \\
&= (\min\{z_{11}, z_{21}, \cdots z_{n1}\}, \min\{z_{12}, z_{22}, \cdots z_{n2}\}, \cdots, \min\{z_{1m}, z_{2m}, \cdots z_{nm}\})
\end{aligned}
$$

The basic idea of TOPSIS method is to construct an ideal target, and the optimal vector and the worst vector above respectively represent the most important ideal supplier and the least ideal and the least important supplier.

The distance between the vector composed of the measurement index of the ith evaluation object (supplier) and the optimal vector and the worst vector is:

$$
D_i^+ = \sqrt{\sum_{j=1}^{m} \omega_j (Z_j^+ - Z_{ij})^2} \qquad D_i^- = \sqrt{\sum_{j=1}^{m} \omega_j (Z_j^- - Z_{ij})^2}
$$

Then we can calculate the score of this evaluation object:

$$
S_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{5}
$$

For each of the 402 suppliers, their corresponding scores were obtained according to the same evaluation criteria. Therefore, we consider the companies with the top 50 scores under this model to be the most important suppliers.

4. Conclusion

The relevant results of the 50 suppliers we sought are as follows:

Table 3. Data related to the 50 most important suppliers (a)

ID	Supply stability parameters	Meet the availability rate	Supply quantity	Average delivery error	Supply flexibility index	Average supply percentage	score
229	36083.8944	0.94583333	354887	1090.46667	227	0.27123593	0.97450465
361	36083.9754	0.87916667	328080	1088.90833	223	0.24198008	0.91395599
108	36078.2807	0.94583333	240950	984.229167	175	0.19394213	0.74249561
140	36068.7977	0.88636364	302047	365.225	35	0.05291047	0.67421262
151	36059.6608	0.95416667	194498	811.241667	187	0.12034442	0.64191779
340	36084.1211	0.94166667	171426	1108.9	201	0.16104432	0.62520493
282	36083.2653	0.9875	169340	1107.92083	219	0.12677921	0.62185339
275	36084.8333	0.94583333	158553	1109.6125	189	0.12452392	0.59393911
329	36084.4677	0.94166667	156518	1110.59167	194	0.12315541	0.59122671
131	36083.955	0.90833333	137512	1103.50417	191	0.12929449	0.55994134
308	36071.4805	0.91666667	136998	905.958333	208	0.1207601	0.55818938
330	36068.6748	0.9125	136652	959.925	196	0.11745222	0.55455427
356	36082.5372	0.95	130307	1101.6875	211	0.09342847	0.55201484
306	36084.4581	0.95416667	126096	1109.55833	192	0.09298249	0.54267207
268	36084.8396	0.9375	129786	1109.55833	157	0.09862867	0.5374758
139	36069.5944	0.96875	151862	1003.43333	52	0.04287531	0.52521188
194	36084.6086	0.94583333	101365	1111.22917	143	0.07670831	0.49418133
352	36084.0699	0.91666667	89031	1110.17083	189	0.06936005	0.48561315
143	36078.4465	0.89583333	82787	1062.19583	202	0.06311471	0.47620482

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348	35989.7101	0.91959799	92421	800.091667	130	0.03135758	0.45819655
284	36075.4441	1	46597	1106.78333	173	0.03391602	0.44708054
307	36056.9251	0.97093023	78196	1012.17917	49	0.03188084	0.4388051
247	36084.7407	0.94583333	56698	1108.38333	110	0.04287329	0.43209814
395	36061.4747	0.86904762	75843	987.9875	69	0.04043618	0.42113792
365	36083.9502	0.95	41631	1108.49583	107	0.03217552	0.41742155

Continued Table (b):

ID	Supply stability parameters	Meet the availability rate	Supply quantity	Average delivery error	Supply flexibility index	Average supply percentage	score
374	35970.2145	0.99583333	49224	1108.74583	46	0.01245156	0.41674586
31	36084.2873	0.925	41207	1108.57083	99	0.03915335	0.41133243
37	36060.1925	0.90062112	50686	1040.49583	83	0.02846864	0.40688809
364	36080.3741	0.94166667	28763	1110.17917	88	0.02346225	0.4002787
367	36080.6655	0.9	26335	1105.85417	120	0.02414592	0.39754463
40	36082.9085	0.90416667	31905	1109.39583	88	0.02754744	0.39552921
218	36083.2031	0.92916667	15483	1108.19583	95	0.01155885	0.3885194
338	36069.1345	0.94117647	30109	1077.69583	34	0.01316212	0.3883526
80	36083.2565	0.875	19237	1109.80417	102	0.0142024	0.38187704
244	36079.2484	0.87083333	16406	1108.8125	108	0.0118806	0.38023668
55	36073.3953	0.9	24041	1077.48333	55	0.01755425	0.37974954
126	36009.4333	0.84	47540	758.1875	71	0.02118813	0.37819841
178	36070.9904	1	163	1111.12083	9	0.00011534	0.3779085
53	36067.013	1	77	1111.22083	7	5.18E-05	0.37761742
346	36080.117	0.87083333	23240	1105.16667	69	0.0218005	0.37718597
239	35974.0864	0.9862069	430	1110.9	9	0.00031357	0.37532195
67	36082.6242	0.98816568	233	1111.07917	4	0.00017459	0.37502528
174	36080.1652	0.98412698	346	1110.90417	8	0.00031662	0.37476802
362	36075.1648	0.98571429	91	1111.24583	4	6.93E-05	0.37445976
3	36077.6765	0.85427136	13138	1106.5375	106	0.0088686	0.37374831
342	36075	0.975	224	1111.09167	14	0.00015978	0.37362024
221	36080.8163	0.97619048	392	1110.8875	8	0.00031799	0.37321163
379	36037.5215	0.97297297	249	1111.16667	11	0.00016916	0.37284553
294	36084.1985	0.87916667	18842	1108.74583	53	0.01420215	0.37205192
30	36056.0847	0.96551724	162	1111.14167	11	0.00012817	0.3713024

This paper proposes a set of methods to measure the supply characteristics and supply capacity as well as the decision-making of supplier selection, in which the measurement indicators are the aspects that most enterprises need to consider, so this model can be easily transferred to the partner selection of other enterprises.

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