Researches on suppliers selection based on improved AHP-TOPSIS method

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Abstract. Selection of supplier can be considered as the significant strategic decision for company’s competitive advantage. Generally, the scales of criteria for selection were used to evaluate the performance of suppliers. But the traditional criteria are limited to reflect the comprehensive ability of the suppliers. Meanwhile, the quantitative scale, which is used to evaluate the suppliers, is too subjective to describe the real station of suppliers. Therefore, the improved analytic hierarchy process (AHP) is conducted to reanalyze the criteria and distribute the weight for each criterion. Technical for order preference by similarity to ideal solution (TOPSIS) used to calculate the relative proximity for each supplier and rank them based on the corresponding information. Finally, the calculate process is programmed by Excel VBA and MATLAB respectively. The two results show the same ranking order, which verify the improved AHP-TOPSIS method can effectively guide company to select supplier.

1. Introduction
Suppliers can be considered as inevitable sources of external risks in modern supply chains [1]. Supplier evaluation and selection is a significant strategic decision for reducing operating costs and improving organizational competitiveness to develop business opportunities [2]. However, the traditional criteria are limit to evaluate the comprehensive ability for the suppliers, which can not offer a reasonable selection for the company to survive in fierce competition in the market. For example, the culture, flexibility, delivery are seldom considered in the criteria system [3]. Meanwhile, the criteria, which used in AHP, is distributed the weight by experts opinions. This process can bring the subjective factor to calculation result which fails to obtain the reasonable solution. Therefore, the new criteria system and objective methods are widely study in the supplier selection problem. A decision model for selection of suppliers is propose and fuzzy TOPSIS method is used to reduce the subjectivity of experts’ suggestions [4]. The same approaches such as the grey-based method, best worst method, integrated framework method [5], grey system [6] and rough set methodologies [7] and other methods can effectively reduce the subjectivity degree. Some new methods, which avoid the criteria scale, also be proposed, such as chance-constrained data envelopment analysis [8], integrated QFD-MCDM framework [9] and other methods can solve the ranking of supplier. With the development of cities, the environment and green supply are emphasized in the selection process. Fuzzy axiomatic design approach, which consider the environmental protection and sustainable development, is proposed to evaluate the suppliers [10]. The strength of the fuzzy NGT-VIKOR based solution approach is its practical applicability and evaluation of green supplier development programs under limited or no quantitative information [11]. AHP-Entropy-TOPSIS framework also be adopted...
to solve the green suppliers selection problem [12]. Furthermore, the multi-criteria decision making approaches are concluded to solve the selection of green supplier and normal suppliers [13,14]. In this paper, the criteria of supplier selection are reanalyzed to fit the comprehensive requirements from the market competition. Then, the improved AHP method distributes the weight for each criterion. Finally, the TOPSIS is adopted to calculate the quantitative result and rank suppliers. EXCEL VAB and MATLAB are used to program the calculation process and verify the effectiveness of method.

2. Using AHP to allocate index weight

2.1. Reanalyzing the criteria in AHP model

The traditional criteria which were used to evaluate the suppliers can be summarized as QSTC (Q: quality, S: serve, T: time, C: cost) in figure 1. However, it only focuses on the static performance for the company rather than the dynamic performance which cannot help the leader of company determine the selection of suppliers. Meanwhile, the traditional criteria fail to reflect the comprehensive competitive ability for the suppliers in the future market competition. Therefore, the sub-criteria and AHP model are modified based on the Delphi method to add more criteria to complete the evaluate system and formulate the improved AHP model. Comparing with original evaluate system and summarizing the questionnaire result, the experts group give the suggestion that add the enterprise culture to the criteria system and redistribute the weight for each sub-criteria. The improved AHP model and criteria system is shown in figure 2.

![Figure 1. Original AHP model and criteria](image1)

![Figure 2. Improved AHP model and criteria](image2)

2.2. Constructing judgment matrix

AHP uses a pair-wise comparison of the criteria importance with respect to the goal. This pair-wise comparison allows finding the relative weight of the criteria with respect to the main goal. Therefore, the defined scale or ratio should be introduced for the judgment matrix. If the quantitative data can be used to consist of the matrix, the comparisons can be easily expressed and the calculation work of AHP will be considerably reduced.

In this paper, index scale is introduced for the pair-wise comparison. In the general scale table, number 9 indicates the extremely important for pair-wise comparison of the criteria. However, in the index scale, the equation \( a^3 = 9 \) is used to express the same degree and the value \( a \) can be accurately solved that \( a = 1.316 \). Before the compare between the two criteria, the important scale \( a \) should be given. The other corresponding index scale numbers are shown in the table 1. Furthermore, the quantitative expert opinion is shown in table 2.
Based on the information in the table 2, the judgment matrix $M$ of goal hierarchy $M$ with respect to first criteria hierarchy ($A$-$M$ matrix) can be expressed as

$$
M = \begin{bmatrix}
1 & 2.618 & 1.618 & 2.058 & 3.330 & 5.388 \\
0.382 & 1 & 2.058 & 2.058 & 2.618 & 4.236 \\
0.468 & 0.486 & 1 & 1 & 3.330 & 4.236 \\
0.468 & 1.618 & 1 & 1 & 3.330 & 5.388 \\
0.300 & 0.382 & 0.300 & 0.300 & 1 & 2.618 \\
0.186 & 0.236 & 0.236 & 0.186 & 0.382 & 1
\end{bmatrix}
$$

2.3. The check of consistency

Next step is to calculate the hierarchical single sorting and consistency check which are the normal AHP calculation processes. The result of the consistency check for $A$-$M$ matrix can be shown on the table 3. The same calculate processes can be used to solve the consistency check of $A1$-$B$, $A2$-$B$, $A3$-$B$, $A4$-$B$, $A5$-$B$, $A6$-$B$. All of judgment matrixes pass the test of consistency check. The final weight of criteria is shown on the table 4.

### Table 1 Index scale and meaning for judgment matrix

| Subjective feeling | Equally important | Slightly important | Obviously important | Strongly important | Extremely important | Form |
|--------------------|-------------------|--------------------|---------------------|--------------------|--------------------|------|
| Index form         | $a^0=1$           | $a^2=1.618$        | $a^4=2.618$         | $a^6=4.236$        | $a^8=6.854$        | $a^{k-1}$ |
| Reciprocal form    | $a^0=1$           | $a^2=0.618$        | $a^4=0.382$         | $a^6=0.236$        | $a^8=0.146$        | $a^{1-k}$ |

### Table 2 Quantitative scale for human feeling

| Subjective feeling | Equally important | Slightly important | Obviously important | Strongly important | Extremely important | Form |
|--------------------|-------------------|--------------------|---------------------|--------------------|--------------------|------|
| m:n                | 0.9-1.1           | 1.1-1.3            | 1.3-1.5             | 2.5-4              | 4-6                | 8-10 |

### Table 3 Matrix A-M consistency check calculation process

| Matrix | $n$(dimension) | $\lambda$ max | CI=$(\lambda$ max-$n$)/(n-1) | RI | CR=CI/RI |
|--------|----------------|---------------|------------------------------|----|---------|
| $M$    | 6              | 6.191822      | 0.038364                     | 1.24| 0.030939 |

### Table 4 The weight of criteria for suppliers selection

| Criteria | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ |
|----------|-------|-------|-------|-------|-------|-------|
| Weight of criteria | 0.3193 | 0.1821 | 0.1681 | 0.2138 | 0.0754 | 0.0413 |

3. Ranking suppliers based on the TOPSIS

TOPSIS is further used to calculate the decision matrix. The suppliers which need be assessed by company is indicated as $C_i$ ($i=1, 2, 3, \ldots, m$), $m$ is the number of suppliers, the components which are offered for the company from each suppliers should be the same one. The assess criteria is $B_j$ ($j=1, 2, 3, \ldots, n$). The assess value of the alternatives set $C = \{C_1, C_2, C_3, \ldots, C_m\}$ with respect to criteria set can be express as $x_{ij}(i=1,2,3,\ldots,m; j=1,2,3,\ldots,n)$. Furthermore, the decision matrix is unified to obtain the normative decision matrix.
After standardizing the relevant data of the evaluation criteria for scheme, the positive and negative ideal solution of the data is calculated to obtain the reference scale. The corresponding scales are used to evaluate the best supplier and worst supplier. The weighted decision matrix and positive and negative ideal solutions are shown in table 5.

The Euclidean distance between each supplier with the best supplier and the worst supplier is calculated. Furthermore, the relative proximity $\eta_i$ between each supplier and the best supplier is solved to find which result is close to the positive ideal solution. More close to the positive ideal solution, the better the supplier is; on the contrary, the worse it is. The calculation results are shown in table 6.

| Supplier | $S_{d1}^+$ Euclidean distance value | $S_{d2}^+$ Euclidean distance value | $\eta$ |
|----------|------------------------------------|------------------------------------|-------|
| 1        | 0.180124632                        | 0.140122322                       | 0.43754459 |
| 2        | 0.157910418                        | 0.132233352                       | 0.455751133 |
| 3        | 0.045845924                        | 0.231561669                       | 0.834734431 |
| 4        | 0.091509891                        | 0.205018689                       | 0.691396051 |
| 5        | 0.135056632                        | 0.135056632                       | 0.5     |

4. Results
The improved AHP is used to identify the weight for each criteria, furthermore, the TOPSIS is used to rank the suppliers. The calculation process is shown on the above chapter, the final solution is calculated by the EXCEL VBA and MATLAB which is shown in table 7.

Based on the value of relative proximity, supplier 3 obtains the largest score 0.28, which means supplier 3 is the best supplier among the five selections. The supplier 4 obtains 0.23 that ranks second, so the supplier 3 and supplier 4 should be considered as the corporate supplier.

For the criteria weight, quality, cost, technology service and supply are account the mainly weight in the first hierarchy criteria which account 31.93%, 21.38%, 18.21% and 16.81% respectively.

| Supplier  | $S_{d1}^+$ Euclidean distance value | $S_{d2}^+$ Euclidean distance value | $\eta$ |
|-----------|------------------------------------|------------------------------------|-------|
| Excel VBA | 0.1461                             | 0.1524                             | 0.1929 |
| MATLAB    | 0.1460                             | 0.1521                             | 0.1926 |
| Relative error | 0.068%                             | 0.192%                             | 0.156% |

5. Conclusion
In this paper, the improved AHP-TOPSIS method is proposed to solve the multi-goal selection of supplier. Firstly, the traditional AHP model is modified to complete the criteria system of suppliers, the company culture is added to evaluate the performance of the five suppliers. Secondly, the weight of each criterion is calculated by the AHP, the index scale is adapted to express the quantitative experts’ opinion. Thirdly, TOPSIS uses the weight of criteria which are obtained from the AHP calculation to rank the supplier. The top two suppliers are finally selected to establish the corporation relationship. Comparing with the experts ranking, the ranking which solved by AHP-TOPSIS method is same to the experts ranking. Therefore, the above result can verify that AHP-TOPSIS can
effectively solve the selection of suppliers.

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