An Application of TOPSIS Method in Supplier Selection Problems with Target Values

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Abstract

Decision makers always consider many criteria in supplier selection problems to find out their best suppliers. Hence, the supplier selection problem belongs to the multiple criteria decision making (MCDM) problem. There are many approaches to solve the MCDM problem, the technique for order preference by similarity to ideal solution (TOPSIS) is one of often used methods. The study used the TOPSIS method and extended the method in supplier selection problems when decision makers set the target value of each criterion. After case testing, the proposed method and procedure can help the managers select the proper supplier in supply chain according to their target values in different criteria.

Keywords: TOPSIS Method, Target Value, Supplier Selection, MCDM

1. Introduction

It is an important job for decision makers to select proper suppliers in their supplier chain systems. They need to use some criteria to evaluate their alternatives and find out which one is the best for them. Hence, the supplier selection problem belongs to the multiple criteria decision making (MCDM) problem (Liao, 2008).

Weber, Current and Benton (1990), Tam and Tummala (2001) and Liao (2008) paid their attention to survey how to select criteria in this problem, such like “the product quality offering price, delivery lead time, service satisfaction, warranty degree, experience and financial stability” (Liao, 2008).

Zeleny (1982) discussed the concept of an ideal solution in MCDM problems. Hwang and Yoon (1981) proposed the technique for order preference by similarity to ideal solution (TOPSIS) to consider the distance from the ideal solution. Saaty (1980) proposed the analytic hierarchy process (AHP) method by using top-down and bottom-up approaches to find out solutions. They proposed different kinds of approaches to solve the MCDM problem.

Hence, Tam and Tummala (2001) used the AHP method to select suppliers. Liao (2008) used Taguchi loss function, AHP and multi-choice goal programming (MCGP) to select right suppliers. Fu (2009) used the TOPSIS method to solve the problem.

Although the TOPSIS method is useful to solve MCDM problems, its approach only considers the maximal or minimal value of each criterion. However, decision makers often set the target value of each criterion in their decision process. The target value of a criterion may be not in maximal or minimal value of the criterion. Hence, the study extended the TOPSIS

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method to solve the supplier selection problems with target values.

2. The Proposed Method and Procedure

The basic concept of the TOPSIS method is to find out the maximal (minimal) value of all alternatives at each criterion to be its positive (negative) ideal solution when the criterion belongs to the effectiveness (cost) set. The paper extended the concept as below.

Definition 1: Let \( x_{ij} \) be the performance value of alternative \( A_i \) at the criterion \( C_j \).

Definition 2: Let \( t_{C_j} \) be the target value of the criterion \( C_j \). Let \( S_E, S_C \) and \( S_T \) denote the effectiveness, cost and target sets, respectively. The target value is given by the decision makers as below.

\[
\begin{align*}
\{ & \geq \max_i \{x_y\}, \quad \text{if } C_j \in S_E, \\
& \in (\min_i \{x_y\}, \max_i \{x_y\}), \quad \text{if } C_j \in S_T, \\
& \leq \min_i \{x_y\}, \quad \text{if } C_j \in S_C. 
\end{align*}
\]

(1)

Definition 3: If \( C_j \) belongs to the set of target \( S_T \), decision makers need to set the values of lower bound \( t_{LB_j} \) and upper bound \( t_{UB_j} \) of \( C_j \) and its relations between both sides of the target value \( t_{C_j} \), the smaller/less is better or the larger/more is better as below in equation (2).

\[
p(x_y) = \begin{cases} 
0, & \text{if } x_y < t_{LB_j}, \\
\frac{x_y - t_{LB_j}}{t_{C_j} - t_{LB_j}}^\alpha & \text{if } t_{LB_j} \leq x_y < t_{C_j}, \\
1, & \text{if } x_y = t_{C_j}, \\
\frac{t_{UB_j} - x_y}{t_{UB_j} - t_{C_j}}^\alpha & \text{if } t_{C_j} < x_y \leq t_{UB_j}, \\
0, & \text{if } x_y > t_{UB_j}.
\end{cases}
\]

(2)

Where \( t_{LB_j} \leq \min_i \{x_y\} < t_{C_j} < \max_i \{x_y\} \leq t_{UB_j} \) and \( \alpha \) is the adjustable factor. If smaller/less (larger/more) is better, then \( 0 < \alpha < 1 \), otherwise \( \alpha > 1 \).

Definition 4: Let \( x_{ij}^* \) and \( t_{C_j}^* \) be defined in equations (3) and (4), respectively.
An Application of TOPSIS Method in Supplier Selection Problems with Target Values

\[ x_{ij}^* = \begin{cases} x_{ij}, & \text{if} \quad C_j \in \{S_E, S_C\}, \quad i \in \mathbb{I}, \quad j \in \mathbb{J} \cap \{1, 2, \ldots, m\}; \\ p(x_{ij}), & \text{if} \quad C_j \in S_T. \end{cases} \quad (3) \]

\[ t_{Cj}^* = \begin{cases} t_{Cj}, & \text{if} \quad C_j \in \{S_E, S_C\}, \\ 1, & \text{if} \quad C_j \in S_T. \end{cases} \quad (4) \]

Definition 5: The normalized values of \( x_{ij}^* \) and \( t_{Cj}^* \) are denoted as \( n_{ij} \) and \( n_{tCj} \), and defined in equation (5), respectively.

\[ n_{ij} = \frac{x_{ij}^*}{\sqrt{\sum_{i=1}^{m} (x_{ij}^*)^2}}, \quad n_{tCj} = \frac{t_{Cj}^*}{\sqrt{\sum_{i=1}^{m} (t_{Cj}^*)^2}}, \quad i \in \mathbb{I}, \quad j \in \mathbb{J}. \quad (5) \]

Definition 6: The weighted values of \( n_{ij} \) and \( n_{tCj} \) are denoted as \( v_{ij} \) and \( v_{Cj} \), and defined in equation (6), respectively.

\[ v_{ij} = n_{ij} \cdot w_j, \quad v_{Cj} = n_{tCj} \cdot w_j, \quad i \in \mathbb{I}, \quad j \in \mathbb{J}. \quad (6) \]

Where \( 0 \leq w_j \leq 1 \) and \( \sum_{j=1}^{n} w_j = 1 \).

Definition 7: Let \( I^+ \) be the positive-ideal solution of all alternatives.

\[ I^+ = \{v_1^+, v_2^+, \ldots, v_n^+\} = \{v_{Cj}^* \mid C_j \in \{S_E, S_C, S_T\}\}, \quad i \in \mathbb{I}, \quad j \in \mathbb{J}. \quad (7) \]

Definition 8: Let \( I^- \) be the negative-ideal solution of all alternatives.

\[ I^- = \{v_1^-, v_2^-, \ldots, v_n^-\} = \{\min_j v_{ij} \mid C_j \in \{S_E, S_T\}\}, \quad (\max_j v_{ij} \mid C_j \in S_C\} \}, \quad i \in \mathbb{I}, \quad j \in \mathbb{J}. \quad (8) \]

Definition 9: Let \( S_i^+ \) be the distance between alternative \( A_i \) and the positive-ideal solution.

\[ S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_i^+)^2}, \quad i \in \mathbb{I}. \quad (9) \]

Definition 10: Let \( S_i^- \) be the distance between alternative \( A_i \) and the negative-ideal solution.
\( S_j^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, i \in I. \) (10)

Definition 11: The preference value \( C_i^* \) of the alternative \( A_i \) is defined in equation (11).

\[
C_i^* = \frac{S_i^-}{S_i^- + S_i^+}, i \in I. \quad (11)
\]

The procedure of the TOPSIS method in supplier selection problems with target values is listed as below.

Step 1: Calculate the value \( x_{ij}^* \) and \( t_{ij}^* \) by equations (2)-(4), \( i \in I, j \in J \).

Step 2: Calculate the normalized value \( n_{ij} \) and \( n_{ij}^* \) by equation (5), \( i \in I, j \in J \).

Step 3: Calculate the weighted normalized value \( v_{ij} \) and \( v_{ij}^* \) by equation (6), \( i \in I, j \in J \).

Step 4: Find out the positive-ideal solution \( I^* \) and negative-ideal solution \( I^- \) by equations (7) and (8).

Step 5: Calculate the distance from the positive-ideal solution of each alternative, \( S_i^* \) by equation (9), and the distance from the negative-ideal solution of each alternative, \( S_i^- \) by equation (10).

Step 6: Calculate the \( C_i^* \) by equation (11). Arrange alternatives and make choice, the larger/more is better.

### 3. A Numerical Example

There are five alternative suppliers, named A, B, C, D and E. The decision maker decides to consider seven criteria, “defective rate”, “price”, “delivery time”, “service satisfaction”, “warranty degree”, “experience time” and “financial stability”, to evaluate and select one supplier. The data are listed in Table 1.

The first three criteria belong to the set of \( S_C \), the less/lower is the better. The last one belongs to the set of \( S_T \), its target value is 900, its lower bound is 500, and its upper bound is 1500 and the smaller/less is better, \( \alpha = .5 \). The others belong to the set of \( S_E \),
the larger/more is the better. The study used the entropy method (Hwang and Yoon, 1981; Zeleny, 1982) to calculate the weight data of each attribute listed in Table 3.

Hence, the study calculated the results step by step as below. Steps 1 and 2: Calculate the normalized value in Table 2.

Step 3: Calculate the weighted normalized value in Table 4.
Step 4: Find out the positive-ideal solution \( I^+ \) and negative-ideal solution \( I^- \) in Table 4.
Step 5: Calculate the distances from the positive-ideal solution \( S_i^+ \) and the negative-ideal solution \( S_i^- \) of each alternative in Table 5.
Step 6: Arrange alternatives in Table 5

**Table 1  The data of suppliers**

<table>
<thead>
<tr>
<th>Item</th>
<th>Defective rate (%)</th>
<th>Price ($)</th>
<th>Delivery time (day)</th>
<th>Service satisfaction (%)</th>
<th>Warranty degree (%)</th>
<th>Experience time (year)</th>
<th>Financial stability ($million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.6</td>
<td>110</td>
<td>1.65</td>
<td>95%</td>
<td>90%</td>
<td>5</td>
<td>700</td>
</tr>
<tr>
<td>B</td>
<td>1.8</td>
<td>100</td>
<td>1.85</td>
<td>82%</td>
<td>88%</td>
<td>9</td>
<td>1000</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>105</td>
<td>1.6</td>
<td>90%</td>
<td>85%</td>
<td>8</td>
<td>1200</td>
</tr>
<tr>
<td>D</td>
<td>1.5</td>
<td>108</td>
<td>1.5</td>
<td>70%</td>
<td>80%</td>
<td>9</td>
<td>1000</td>
</tr>
<tr>
<td>E</td>
<td>1.4</td>
<td>115</td>
<td>2</td>
<td>65%</td>
<td>82%</td>
<td>12</td>
<td>600</td>
</tr>
</tbody>
</table>

**Table 2  The normalized data**

<table>
<thead>
<tr>
<th>Item</th>
<th>Defective rate</th>
<th>Price</th>
<th>Delivery time</th>
<th>Service satisfaction</th>
<th>Warranty degree</th>
<th>Experience time</th>
<th>Financial stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.4822</td>
<td>0.4567</td>
<td>0.4267</td>
<td>0.5232</td>
<td>0.4731</td>
<td>0.2516</td>
<td>0.4575</td>
</tr>
<tr>
<td>B</td>
<td>0.5425</td>
<td>0.4152</td>
<td>0.4784</td>
<td>0.4516</td>
<td>0.4626</td>
<td>0.4528</td>
<td>0.5392</td>
</tr>
<tr>
<td>C</td>
<td>0.3014</td>
<td>0.4359</td>
<td>0.4137</td>
<td>0.4956</td>
<td>0.4468</td>
<td>0.4025</td>
<td>0.3235</td>
</tr>
<tr>
<td>D</td>
<td>0.4521</td>
<td>0.4484</td>
<td>0.3879</td>
<td>0.3855</td>
<td>0.4205</td>
<td>0.4528</td>
<td>0.5392</td>
</tr>
<tr>
<td>E</td>
<td>0.4219</td>
<td>0.4775</td>
<td>0.5172</td>
<td>0.3580</td>
<td>0.4310</td>
<td>0.6038</td>
<td>0.3235</td>
</tr>
</tbody>
</table>

**Table 3  The weight data**

<table>
<thead>
<tr>
<th>Item</th>
<th>Defective rate</th>
<th>Price</th>
<th>Delivery time</th>
<th>Service satisfaction</th>
<th>Warranty degree</th>
<th>Experience time</th>
<th>Financial stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.1720</td>
<td>0.0107</td>
<td>0.0540</td>
<td>0.1011</td>
<td>0.0093</td>
<td>0.3517</td>
<td>0.3011</td>
</tr>
</tbody>
</table>
Table 4 The weighted normalized data and the ideal solutions

<table>
<thead>
<tr>
<th>Item</th>
<th>Defective rate</th>
<th>Price</th>
<th>Delivery time</th>
<th>Service satisfaction</th>
<th>Warranty degree</th>
<th>Experience time</th>
<th>Financial stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.0829</td>
<td>0.0049</td>
<td>0.0230</td>
<td>0.0529</td>
<td>0.0044</td>
<td>0.0885</td>
<td>0.1597</td>
</tr>
<tr>
<td>B</td>
<td>0.0933</td>
<td>0.0044</td>
<td>0.0258</td>
<td>0.0457</td>
<td>0.0043</td>
<td>0.1593</td>
<td>0.1569</td>
</tr>
<tr>
<td>C</td>
<td>0.0518</td>
<td>0.0047</td>
<td>0.0223</td>
<td>0.0501</td>
<td>0.0042</td>
<td>0.1416</td>
<td>0.0565</td>
</tr>
<tr>
<td>D</td>
<td>0.0778</td>
<td>0.0048</td>
<td>0.0209</td>
<td>0.0390</td>
<td>0.0039</td>
<td>0.1593</td>
<td>0.1569</td>
</tr>
<tr>
<td>E</td>
<td>0.0726</td>
<td>0.0051</td>
<td>0.0279</td>
<td>0.0362</td>
<td>0.0040</td>
<td>0.2124</td>
<td>0.1129</td>
</tr>
<tr>
<td>I^-</td>
<td>0.0933</td>
<td>0.0051</td>
<td>0.0279</td>
<td>0.0362</td>
<td>0.0039</td>
<td>0.0885</td>
<td>0.0565</td>
</tr>
<tr>
<td>I^+</td>
<td>0.0000</td>
<td>0.0044</td>
<td>0.0070</td>
<td>0.0529</td>
<td>0.0046</td>
<td>0.2124</td>
<td>0.2259</td>
</tr>
</tbody>
</table>

Table 5 The solution of proposed method

<table>
<thead>
<tr>
<th></th>
<th>$C_i^*$</th>
<th>Rank</th>
<th>Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.3910</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0.4881</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.2650</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>0.5117</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0.5015</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

In Table 5, the best supplier of decision makers is alternative D which obtained the maximal preference value among all alternatives.

4. Conclusions

The study discussed that how to select the best supplier in supplier selection problems when decision makers set the target value of each criterion. Although many approaches can solve the problem, the study proposed a method and a procedure to extend the TOPSIS method to solve the problem. After numerical example testing, the method and procedure can help decision makers select their best supplier according their target values.
References


