Applying Fuzzy PROMETHEE Method for Evaluating IS Outsourcing Suppliers

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Abstract

The demand for outsourcing in the information systems (IS) field has become a part of basic corporate strategy and has experienced a considerable growth in recent years. The process of IS outsourcing is always involved in a variety of situations and decision problems under fuzzy environment. The selection of appropriate outsourcing partners thus is one of the most important decision issues for organizations. The aim of this paper is to present the fuzzy Preference Ranking Organization METHod for Enrichment Evaluation (fuzzy PROMETHEE) method to evaluate four potential suppliers based on seven criteria and four decision makers by using a realistic case study. The results of the rankings provide the reference to assist decision makers or organizations to improve the efficiency of their IS outsourcing decision processes come up with the best solutions.

Keywords – Fuzzy PROMETHEE, information system outsourcing, FMCMD.

1. Introduction

The evaluation and selection of contraction works, in terms of contractor for every single category, has been made in many evaluation criteria such as cost, quality, and so forth. For the conventional manner of evaluation, once the weight for each of the criterion would be given, which will be then summed up and ranked. During the process of the evaluation in practice, the decision to weight or rate score of its information would be complicated with fuzzy decision problems. However, decision making is the process of finding the best option from all of the feasible alternatives for decision problem solutions. Several approaches and relevant methods have been developed and proposed to deal with multi-criteria decision problems. One of the multi-criteria decision making (MCDM) methods for the multi-criteria problem analysis is the PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation) which was developed by Brans et al. [3]. It is a ranking method and a quite simple conception and application compared to other methods [6]. However, the PROMETHEE method likes other traditional MCDM methods lack of ability to process fuzzy data in the actual decision-making environment. To resolve the vagueness, ambiguity and subjectivity of human judgment, fuzzy sets theory [9] was introduced to express the linguistic terms in the decision making (DM) process. Thus, applications on solving MCDM problems by fuzzy sets theory have been published in many professional journals of diversified disciplines.

In this paper, we present a fuzzy PROMETHEE approach to evaluate IS outsourcing suppliers for the selection of the best fit among all candidates. Since information systems (IS) outsourcing has become more pervasive in which information technology (IT) managers and the chief information officers (CIOs) cannot ignore it, and has witnessed rapid growth in recent years [1, 2, 8].

2. Fuzzy PROMETHEE

Ho [7] combined the fuzzy set theory and PROMETHEE method developed the Fuzzy PROMETHEE, which is more flexible. The following steps are required for the implementation of the method:

Step 1: Determine alternatives, criteria and decision-makers.
Suppose there are $m$ alternatives, $k$ criteria and $n$ decision-makers.

**Step 2:** Define linguistic values and their corresponding fuzzy number.

This study adopts five linguistic variables, which are one of eight kinds of linguistic terms proposed by Chen and Hwang [5], namely “very low”, “low”, “medium”, “high” and “very high”, which were expressed in triangular fuzzy numbers, to assess the importance weights of performance criteria. Also, the evaluators adopted linguistic terms (see Table 1), including “worst”, “poor”, “fair”, “good” and “best”, to express their opinions about the rating of every outsourcer regarding each performance criteria.

**Step 3:** Aggregate the decision-maker’s estimation.

The average priority weight of each criterion is

$$\tilde{w}_j = \frac{1}{n} \sum_{i=1}^{n} \tilde{w}_{ij} = \frac{1}{n} [\tilde{w}^{ij}_1(+)\tilde{w}^{ij}_2(+)\cdots(+)\tilde{w}^{ij}_n]$$

(1)

The evaluated value of the alternative $i$ ($A_i$) under the criterion $j$ ($C_j$) is

$$\tilde{x}_{ij} = \frac{1}{n} [\tilde{x}^{ij}_1(+)\tilde{x}^{ij}_2(+)\cdots(+)\tilde{x}^{ij}_n]$$

(2)

**Step 4:** Compute the average fuzzy weight and construct the fuzzy decision matrix.

$$\tilde{D} = [\tilde{x}_{ij}]_{m \times k} = A_j = \begin{bmatrix}
\tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1k} \\
\tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2k} \\
\vdots & \vdots & \ddots & \vdots \\
\tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mk}
\end{bmatrix}$$

(3)

$\tilde{x}_{ij}$ indicates the evaluated value of the alternative $i$ ($A_i$) under the criterion $j$ ($C_j$).

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \cdots, \tilde{w}_k]$$

(4)

$\tilde{w}_j$ denotes the priority weight of the criterion $j$.

$\tilde{x}_{ij}$ and $\tilde{w}_j$ are the linguistic variable of the triangle fuzzy number.

**Step 5:** Construct the fuzzy preference function.

[5-1] Let $\bar{A}$ be a set of alternatives and $a$ and $b$ are two alternatives of set $A$, the preference function $\tilde{P}_j(a,b)$ can be defined as follows:

$$\tilde{P}_j(a,b) = \begin{cases} 
0 & \tilde{x}_{aj} \geq \tilde{x}_{bj} \\
\tilde{x}_{aj} - \tilde{x}_{bj} & \tilde{x}_{aj} > \tilde{x}_{bj}
\end{cases}$$

(5)

where the preference function $\tilde{P}_j(a,b)$ means the outranking intensity that $a$ is superior to $b$.

[5-2] The preference function $\tilde{P}_j(a,b)$ for a criterion $j$ returns, for a difference between two evaluation on that criterion. The outranking relation construct from the pairwise comparison of alternatives.

$$\tilde{x}_{aj} > \tilde{x}_{bj} \iff aPb \quad (a \text{ outranks } b)$$

(6)

**Step 6:** Define the multi-criteria preference index to decide the valued outranking relation.

If each criterion $C_j$ ($j = 1, 2, ..., k$) is with preference function $\tilde{P}_j$, the multi-criteria preference index ($\tilde{\pi}(a,b)$) can be defined as follows:

$$\tilde{\pi}(a,b) = \frac{\sum_{j=1}^{k} \tilde{P}_j(a,b)}{\sum_{j=1}^{k} \tilde{w}_j}$$

(7)

Suppose the priority weight of each criterion is the same, then use “equation (7),” or use the average weighted as “equation (8)”.

**Step 7:** Calculate the flow to preorder the alternatives.

[7-1] Fuzzy PROMETHEE I: Demonstrate some alternatives which are unable to compare with each other by using partial preorder.

Outgoing/Leaving Flow is

$$\tilde{\phi}^+(a) = \sum_{y \epsilon A} \tilde{\pi}(a,y), \forall a, y \epsilon A$$

(9)

where $\tilde{\phi}^+(a)$ indicates the sum of preference that $a$ is superior to other alternatives. The higher the $\tilde{\phi}^+(a)$, the better the alternative $a$.

Incoming/Entering Flow is

$$\tilde{\phi}^-(a) = \sum_{y \epsilon A} \tilde{\pi}(a,y), \forall a, y \epsilon A$$

(10)

where $\tilde{\phi}^-(a)$ indicates the sum of preference that other alternatives are superior to $a$, the smaller the $\tilde{\phi}^-(a)$, the better the alternative $a$.

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Table 1. Linguistic variables and their corresponding fuzzy numbers

<table>
<thead>
<tr>
<th>Priority weights of criteria</th>
<th>Fuzzy number</th>
<th>Priority ratings of possible outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low (VL)</td>
<td>(0.00,0.00,0.25)</td>
<td>Worst (W)</td>
</tr>
<tr>
<td>Low (L)</td>
<td>(0.00,0.25,0.50)</td>
<td>Poor (P)</td>
</tr>
<tr>
<td>Medium (M)</td>
<td>(0.25,0.50,0.75)</td>
<td>Fair (F)</td>
</tr>
<tr>
<td>High (H)</td>
<td>(0.50,0.75,1.00)</td>
<td>Good (G)</td>
</tr>
<tr>
<td>Very High (VH)</td>
<td>(0.75,1.00,1.00)</td>
<td>Best (B)</td>
</tr>
</tbody>
</table>
Next is the defuzzification. This study uses maximizing set and minimizing set method which was proposed by Chen [4] to defuzzification.

Maximizing Set $R = \{ (x, f_R(x)) \mid x \in R \}$ and

$$f_R(x) = \begin{cases} \frac{(x-x_1)(x-x_2)}{(x_2-x_1)}, & x_1 \leq x \leq x_2 \\ 0, & \text{otherwise} \end{cases}$$  \hspace{1cm} (11)

Minimizing Set $L = \{ (x, f_L(x)) \mid x \in R \}$ and

$$f_L(x) = \begin{cases} \frac{(x-x_1)(x-x_2)}{(x_2-x_1)}, & x_1 \leq x \leq x_2 \\ 0, & \text{otherwise} \end{cases}$$  \hspace{1cm} (12)

Right Utility $U_R(\tilde{\phi}^+(i)) = \sup_x (f_{\tilde{\phi}^+(x)}(x) \wedge f_R(x))$

Left Utility $U_L(\tilde{\phi}^-(i)) = \sup_x (f_{\tilde{\phi}^-(x)}(x) \wedge f_L(x))$

Total preference valued

$$U_i(\tilde{\phi}^+(i)) = \phi^+(i) = \frac{U_R(\tilde{\phi}^+(i)) + 1 - U_L(\tilde{\phi}^-(i))}{2}$$  \hspace{1cm} (13)

Then, the preference relation and the partial preorder $(P^+, I^+, R)$ as follows:

- $aP^+ b$: \( P \text{ iff } \phi^+(a) > \phi^+(b), \forall a, b \in A \)
- $aI^+ b$: \( I \text{ iff } \phi^+(a) = \phi^+(b), \forall a, b \in A \)

Intersection $I^+$(14) and (15), we can obtain the outranking relation and the partial preorder as follows:

- $aP^+ b$: $P \text{ and } aP^+ b$: $P$
- $aP^+ b$: $P \text{ and } aP^+ b$: I
- $aP^+ b$: I and $aP^+ b$: I
- $aI^+ b$: $a \text{ is indifferent to } b$
- $aP^+ b$: $a \text{ and } b \text{ are incomparable}$, otherwise

[7-2] Fuzzy PROMETHEE II: Compare and rank all alternatives by using complete preorder. This model ranks alternatives according to their net flows. The definition of net flows ($\phi(a)$) is

$$\phi(a) = \phi^+(a) - \phi^-(a), \forall a \in A$$  \hspace{1cm} (17)

The higher the $\phi(a)$, the better the alternative $a$.

The preference relation defines as follows:

- $aP^+ b$: $\phi(a) > \phi(b), \forall a, b \in A$
- $aI^+ b$: $a \text{ is indifferent to } b$
- $aP^+ b$: $\phi(a) = \phi(b), \forall a, b \in A$

Also, in Fuzzy PROMETHEE I, the partial preorder is obtained from the leaving and entering flows. In Fuzzy PROMETHEE II, the consideration of net flow leads to the complete ranking.

**Step8:** Construct valued outranking graph to evaluate the preference ranking of each alternative.

### 3. Case study

The company under study is a bank in Taiwan. It plans to outsource one of their information systems. The managers have agreed to evaluate their outsourcers $(A_1, A_2, A_3, A_4)$ under seven different evaluation criteria $(C_1, C_2, ..., C_7)$. Seven criteria include the experience of outsourcer $(C_1)$, the goodwill of outsourcer $(C_2)$, the cooperative ability $(C_3)$, technology skills $(C_4)$, sustainable ability $(C_5)$, management ability of outsourcer $(C_6)$, and general problems $(C_7)$. In this case, there are four decision-makers $(D_1, D_2, D_3, D_4)$.

<table>
<thead>
<tr>
<th>Table 2. The priority weight of criteria</th>
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<tbody>
<tr>
<td>$D_1$</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>$C_1$</td>
</tr>
<tr>
<td>$C_2$</td>
</tr>
<tr>
<td>$C_3$</td>
</tr>
<tr>
<td>$C_4$</td>
</tr>
<tr>
<td>$C_5$</td>
</tr>
<tr>
<td>$C_6$</td>
</tr>
<tr>
<td>$C_7$</td>
</tr>
</tbody>
</table>

According to Eq.(1), weight of each criterion can be calculated, for clarity, example for $C_1$ is shown below:

$$\bar{w}_1 = \frac{1}{4}[VH + VH + H + H] = \frac{1}{4}(0.75, 0.10, 1.00) \otimes (0.75, 0.10, 1.00) \otimes (0.50, 0.75, 1.00) \otimes (0.50, 0.75, 1.00)]$$

$$= \frac{1}{4}(2.5, 3.5, 4.0) = (0.6250, 0.8750, 1.0000)$$

The average fuzzy priority weight of criteria are $C_1 = (0.6250, 0.8750, 1.0000), C_2 = (0.5000, 0.7500, 0.9375), C_3 = (0.6250, 0.8750, 1.0000), C_4 = (0.6875, 0.9375, 1.0000), C_5 = (0.6875, 0.9375, 1.0000), C_6 = (0.4375, 0.6875, 0.9375) \text{ and } C_7 = (0.3750, 0.6250, 0.8125)$.

Then follows the step described in Section 2, we can obtain the multicriteria preference index $\mathcal{R}(a, b)$ as shown in Table 3.
Further, the net flows of each candidate as 
\[ \phi(A_1) = 0.0708 \], \[ \phi(A_2) = 0.0845 \], \[ \phi(A_3) = -0.0725 \] and \[ \phi(A_4) = -0.0808 \]. Therefore, the ranking by the Complete Preorder \( (aP^{III}b) \) are \( A_2P^{III}A_1 \), \( A_1P^{III}A_4 \), and \( A_4P^{III}A_3 \). As stated above, the valued outranking graph constructed are shown in Fig.1. The ranking results indicate that the candidate \( A_2 \) is the best fit among the candidates. Hence, the bank wants to select its IS outsourcing supplier, the best selection is candidate \( A_2 \).

**Figure 1. Complete Preorder---valued outranking graph**

### 4. Conclusion

Multicriteria analysis by the PROMETHEE method can be extended to deal with fuzzy input data. This paper introduced the fuzzy PROMETHEE method and applied in the IS outsourcing supplier evaluation. This study indicates that the proposed method simply and practically provides a ranking of alternative solutions to decision-making problems. The results of the rankings provide the reference to decision makers or organizations in which may lead to improve the efficiency of the IS outsourcing selection process.

### 5. References


