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# A structured methodology for Information Systems Outsourcing Decisions using Fuzzy MCDM

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## Abstract

This paper presents a structured methodology for Information Systems (IS) outsourcing decision problem. The problem of selection among candidate information systems of the IS can be formulated as Multi criteria decision making (MCDM) techniques. Thus, this paper proposes a fuzzy group decision making process to evaluate and select the appropriate Information System Project (ISP) based on fuzzy Analytical Hierarchy Process (FAHP) in an actual case. To achieve our purpose, seven criteria including risk, management, economics, technology, resource, quality, and strategy and five ISPs are considered to find the priority and ranking of each ISP.

**Keywords:** Information system outsourcing, Multi criteria decision making, Fuzzy AHP

## 1. Introduction

Outsourcing in IT/IS area can be defined as "the handing over to a third party management of IT/IS assets, resources, and/or activities for required results" [1]. In general, the causes for IT outsourcing in today's businesses are as follows: cost saving, increase the flexibility of the IS department, focus on IS strategic issues, elimination of troublesome, everyday problems, technology cost saving, improved IS quality, increase the access to new technology, and decrease the risk [2]. In many cases, outsourced IT projects have failed. One of the main reasons of such failure is making inappropriate decisions in outsourcing process [3]. Based on Gartner Group' report, total spending on IT outsourcing worldwide is likely to rise from US $180 billion in 2003 to US $253 billion in 2008 at a compound annual growth rate of 7 percent [4]. Therefore, making a decision scientifically for IT/IS outsourcing problems and management of outsourcing process is important subject for organizations. Organizations intend to know which systems should be outsourced first. Hence, the concentration of this paper is the proposition of a structured methodology to find which systems should be outsourced first. Most researchers have proposed using multi criteria decision making (MCDM) techniques about the selective IS outsourcing and also this technique has become a popular and common tool in literature at least in this problem.

Generally, after reviewing all of the literature in IT/IS outsourcing problem, a structured approach for this problem in fuzzy environment is not found. We apply the Fuzzy-AHP method for evaluation and selection of candidate information systems of the IS in the paper. As an advantage, the AHP enables decision-maker to handle problems in which the subjective judgment of an individual decision-maker constitutes an important role of the decision-making process. Also using fuzzy theory in IS outsourcing decision problem can reduce ambiguities and uncertainties. This paper presents a comprehensive list of required criteria and also a suitable and structured methodology for evaluation and decision making in selection of the candidate information systems for outsourcing. The rest of the paper is organized as follows: Section 2 describes the Fuzzy AHP to IS outsourcing decision problem; in section 3, Fuzzy AHP applied as an empirical illustration. Finally, the conclusions of this work are presented in section 4.

## 2. Fuzzy analytic hierarchy process (FAHP)

Saaty [5] defined AHP as a hierarchical decomposing decision method for a complex multi-criteria decision problem. Traditional methods of AHP can be of no use when uncertainty is observed in data of problems. To address such uncertainties, Zadeh [6] for the first time introduced and then used fuzzy sets theory. Because the real world is actually full of ambiguities or in one word is fuzzy, several researches have combined fuzzy theory with AHP. The steps of the proposed methodology are as follows:

***Step1**: Find Criteria and Alternatives and Establish hierarchal structure*
The organization firstly should specify the alternative strategies and selection criteria for evaluating these alternatives by interviewing the IT staff and managers.

***Step 2**: Gather expert' judgments based on fuzzy number and establish fuzzy pair wise comparison matrix*
The sample questionnaire is used to determine the priorities of the criteria using experts' opinions based on fuzzy numbers. In this paper, triangular fuzzy numbers is used which is illustrated in Figure 1. Equation (1) shows the membership function of a triangular fuzzy number. Triangular fuzzy number is usually shown with *(l, m, u).*

$$U(x) = \begin{cases} \dfrac{x-l}{m-l} & 1 \le \text{x} \le m \\ \dfrac{u\text{-x}}{u\text{-}m} & m \le \text{x} \le u \\ 0 & \text{Otherwise} \end{cases} \qquad (1)$$

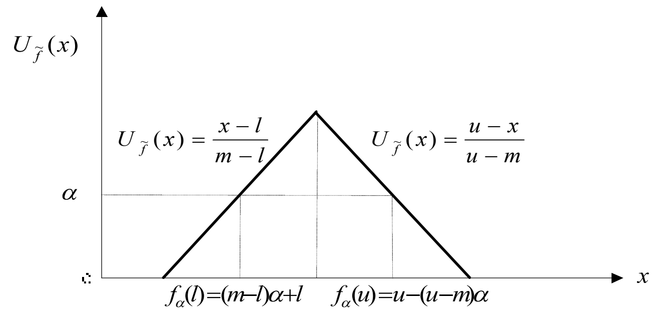

Figure 1: Triangular Fuzzy Number

The AHP method proposed by Saaty [5] uses pair-wise comparisons shown in equation (2). The fuzzy judgment matrix can be defined as follows:

$\tilde{A}^k = [\tilde{a}_{ij}]^k$ (2) where $\tilde{a}^k_{ij} = (1,1,1) : \forall i = j$; $\tilde{a}^k_{ij} = 1/\tilde{a}^k_{ij} : \forall i \neq j$ . $\tilde{A}^k$ is the fuzzy judgment matrix of evaluator *k*, $\tilde{a}^k_{ij}$ the fuzzy assessments between criterion *i* and *j* of evaluator *k*, $\tilde{a}_{ij} = (l^k_{ij}, m^k_{ij}, u^k_{ij})$ *n* is the number of the related criteria at this level. FAHP replaces crisp $a_{ij}$ in AHP by triangular fuzzy numbers. Because each number in the matrix shows the opinions of the experts, fuzzy number is the best solution to show expert judgments. To analyze the data and achieve the consensus of the experts, eigenvector method proposed by Buckley [7] is used here. As is shown in equations (3-6), *l, m,* and *n* show the minimum possible, most likely and the maximum possible value of a fuzzy number, respectively. These numbers have following characteristic:

$\tilde{a}^k_{ij} = (l_{ij}, m_{ij}, u_{ij}) : l_{ij} \le m_{ij} \le u_{ij}, l_{ij}, m_{ij}, u_{ij} \in [1/9, 9]$ (3)

The linguistic scale and corresponding triangular fuzzy numbers are illustrated in Table 1 based on Saaty's scale [5].

Table 1: The linguistic scale and corresponding triangular fuzzy numbers

| Fuzzy | Linguistic scales | Scale of fuzzy |
|---|---|---|
| $\tilde{1}$ | Equally important | (1, 1, 1) |
| $\tilde{3}$ | Weakly important | (2, 3, 4) |
| $\tilde{5}$ | Essentially important | (4, 5, 6) |
| $\tilde{7}$ | Very strongly important | (6, 7, 8) |
| $\tilde{9}$ | Absolutely important | (7, 8, 9) |
| $\tilde{2},\tilde{4},\tilde{6},\tilde{8}$ | Intermediate values ( $\tilde{x}$ ) | (x- 1, x, x+1 ) |
| $1/\tilde{x}$ | between two adjacent | (1/( x+ 1), 1/x, 1/ |

***Step 3**: Calculate Consistency Rate (C.R.)*
According to the analysis of Csutora and Buckley [8], let $\tilde{A} = [\tilde{a}_{ij}]$ be a fuzzy judgment matrix with triangular fuzzy number $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ and form $A = [m_{ij}]$. If $A$ is consistent, then $\tilde{A}$ is consistent. Saaty [5] suggested consistency index (C.I.) and consistency rate (C.R) to verify the consistency of the judgment matrix. Saaty [9]

provided a consistency index to measure any inconsistency within the judgments in each pair-wise comparison matrix as well as for the entire hierarchy. The consistency index (C.I.) is formulated as follows:

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \quad (4)$$

where $\lambda_{\max}$ is the maximum eigenvalue, and $n$ is the dimension of matrix. Accordingly, the consistency rate (C.R.) can be computed with the following equation:

$$C.R. = \frac{C.I.}{R.I.} \quad (5)$$

***Step 4****: Test Consistency Rate (C.R.)*
If $C.R. < 0.1$, the estimate is acceptable; otherwise, a new comparison matrix is established.

***Step 5****: Defuzzify each expert's Judgment using CFCS Method*
The method for defuzzification used in this paper is converting fuzzy data into crisp scores method (CFCS) method introduced by Opricovic and Tzeng [10]. The CFCS method can clearly express fuzzy perception, which is based on the procedure of determining the lower and upper scores by fuzzy min and fuzzy max, and the total score is determined as a weighted average according to the membership functions [11]. The steps of CFCS method are as follow:

*1: Normalized matrix*

$$xl_{ij}^k = (l_{ij}^k - \min l_{ij}^k) / \Delta_{\min}^{\max} \quad (6) \qquad xm_{ij}^k = (m_{ij}^k - \min l_{ij}^k) / \Delta_{\min}^{\max} \quad (7)$$

$$xu_{ij}^k = (u_{ij}^k - \min l_{ij}^k) / \Delta_{\min}^{\max} \quad (8) \qquad \text{where} \quad \Delta_{min}^{max} = \max u_{ij}^k - \min l_{ij}^k \quad (9)$$

*2: Computing lower (ls) and upper (us) normalized value:*

$$xls_{ij}^k = xm_{ij}^k / (1 + xm_{ij}^k - xl_{ij}^k) \quad (10) \qquad xus_{ij}^k = xu_{ij}^k / (1 + xu_{ij}^k - xm_{ij}^k) \quad (11)$$

*3: Computing total normalized crisp value:*

$$x_{ij}^k = [xls_{ij}^k(1 - xls_{ij}^k) + xus_{ij}^k] / [1 - xls_{ij}^k + xus_{ij}^k] \quad (12)$$

*4: Computing crisp value:*

$$a_{ij}^{*k} = \min l_{ij}^k + x_{ij}^k \Delta_{\min}^{\max} \quad (13)$$

For all experts' judgments, Equations (6-13) should be implemented separately. After calculating the crisp value for each expert, the consistency Rate of each expert can be also calculated.

***Step 6:*** *Calculate Integrated crisp values, weights and final ranking*
After defuzzifying by using CFCS Method and collecting all consistent crisp judgments for all levels of the hierarchical structure, geometric average is applied to integrated crisp values of $k$ evaluators using Equation (14).

$$a_{ij}^* = \sqrt[k]{\left(a_{ij}^{*1} \times a_{ij}^{*2} \times \ldots \times a_{ij}^{*k}\right)} \quad (14) \qquad A_{ij}^* = [a_{ij}^*] \quad (15)$$

$A_{ij}^*$ is a aggregated crisp judgment matrix and $a_{ij}^*$ is the aggregated crisp assessments of criterion $i$ and criterion $j$ of $k$ experts, $i, j = 1, 2. . . n,$ and $k$ is the number of experts. In the next Step, we can achieve the final weight of the alternatives using Equation (16) and then the decision can be made based on the weight of alternatives. The weights are sorted decreasingly and the first ranked alternative is selected finally.

$$w_i = \frac{(\prod_{j=1}^{n} a_{ij}^*)^{1/n}}{\sum_{i=1}^{n} (\prod_{j=1}^{n} a_{ij}^*)^{1/n}} \qquad i, j = 1, 2, \ldots, n \quad (16)$$

## 3. Experiments and results

In this section, the proposed methodology on an actual case in one of the biggest online bookshop in Iran is implemented. The company's managers have decided to outsource parts of IS functions and wants to know how to decide which candidate systems should be outsourced first. Therefore, when we construct the AHP model, the first element is to look for the criteria for appropriate IS outsourcing decisions. After reviewing, in our actual case, experts finally considered seven criteria including risk, management, economics, technology, resource, quality and strategy. Candidate information systems for outsourcing are facilities management (ISP1), development of internet homepage (ISP2), maintenance of the customer relationship management information system (ISP3), development of the supplier relationship management information system (ISP4), development and maintenance of the online transaction processing system (ISP5) are the candidate information systems for outsourcing. The overall goal is to select the outsourcing system. The steps of the proposed methodology to select the IT outsourcing are described in following with all the specifics.

**Step1**. *Find Criteria and Alternatives and Establish hierarchal structure*

The first step of analytical hierarchy process is to find criteria and alternatives using expert judgment and literature reviews. After that, decision makers will establish hierarchical structure. Different layers of the hierarchy structure of selecting IS outsourcing are sketched in Figure 2.

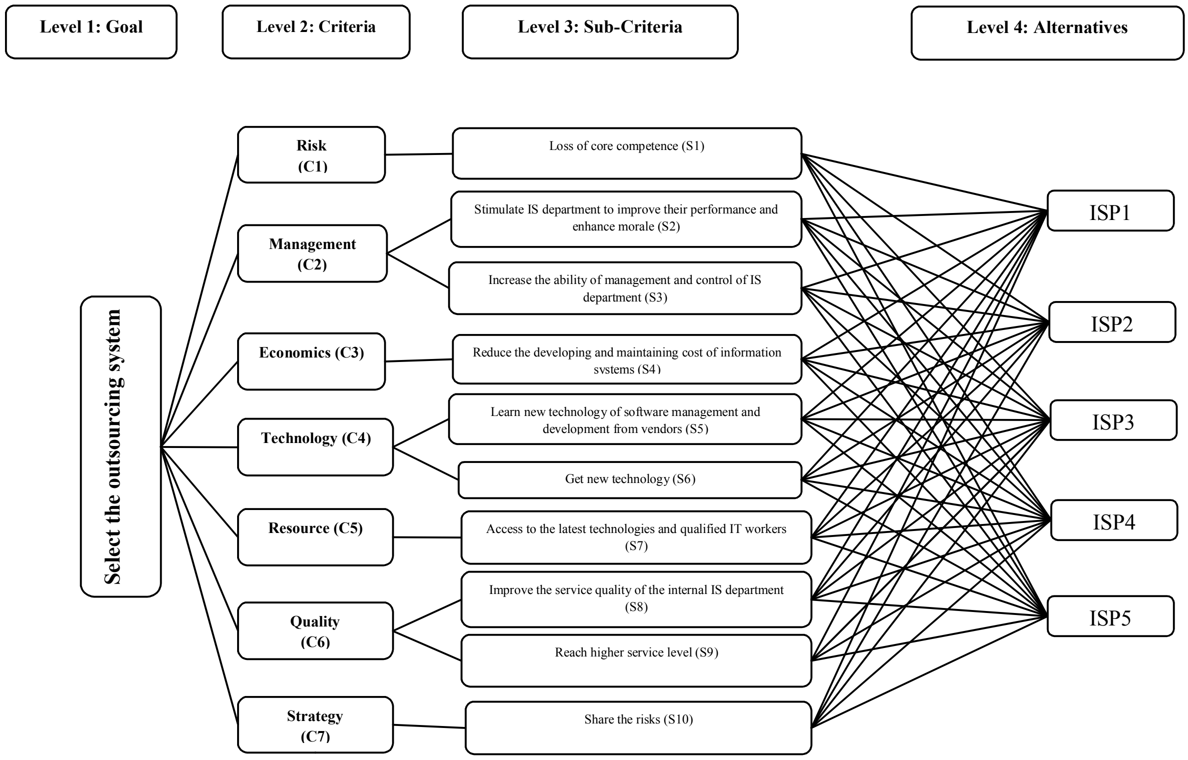


Figure 2: Hierarchy structure for IS outsourcing

**Step 2**: *Gather experts' judgments based on fuzzy number and establish fuzzy pair wise comparison matrix*

In this section, the proposed methodology on an actual case is implemented. According to the linguistic scale and corresponding triangular fuzzy numbers in Table 1, the fuzzy decision matrix for criteria are attained from a verbal questionnaire filled by experts and then these fuzzy decision matrices converted to fuzzy numbers based on Saaty's scale [5]. Table 2 shows a fuzzy decision matrix for one evaluator.

Table 2: Fuzzy judgment matrix with respect to Level 2 for the evaluator 1

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| C1 | (1,1,1) | (0.25,0.333,0.5) | (2,3,4) | (3,4,5 | (2,3,4) | (1,2,3) | (0.333,0.5,1) |
| C2 | (2,3,4) | (1,1,1) | (4,5,6) | (5,6,7 | (3,4,5) | (2,3,4) | (1,2,3) |
| C3 | (0.25,0.333,0 | (0.167,0.2,0.25) | (1,1,1) | (2,3,4 | (0.333,0.5,1 | (0.2,0.25,0.33 | (0.167,0.2,0.2 |
| C4 | (0.2,0.25,0.33 | (0.143,0.167,0. | (0.25,0.333,0. | (1,1,1 | (0.333,0.5,1 | (0.333,0.5,1) | (0.2,0.25,0.33 |
| C5 | (0.25,0.333,0. | (0.2,0.25,0.333) | (1,2,3) | (1,2,3 | (1,1,1) | (0.333,0.5,1) | (0.25,0.333,0. |
| C6 | (0.333,0.5,1) | (0.25,0.333,0.5) | (3,4,5) | (1,2,3 | (1,2,3) | (1,1,1) | (0.2,0.25,0.33 |
| C7 | (1,2,3) | (1,2,3) | (4,5,6) | (3,4,5 | (2,3,4) | (3,4,5) | (1,1,1) |

**Step 3**: *Calculate Consistency rate (C.R.)*

Like mentioned above in step 4 proposed methodology, if $\tilde{A} = [\tilde{a}_{ij}]$ be a fuzzy judgment matrix with triangular fuzzy number (e.g. data in Table 2), to calculate consistency rate, firstly we form $A = [m_{ij}]$. Then the consistencies of fuzzy judgment matrix (Table 2) are evaluated using Equations (4-5) is used to determine maximum eigenvalue ($\lambda_{\max}$) is equal to 7.6771, and so using Equations (4-5) we have:

$$C.I. = \frac{7.6771 - 7}{6} = 0.11285 \qquad C.R. = \frac{0.11285}{1.32} = 0.0855 < 0.1$$

***Step 4***: *Test Consistency Rate*

If judgments of the evaluators were inconsistent, we asked them to repeat the pair-wise comparison processes until the consistency index was less than 0.1. The result shows that the decision matrix for the second level of the proposed hierarchical structure for first evaluator is consistent.

***Step 5***: *Defuzzify each expert's Judgment using CFCS Method*

To deffuzify the triangular fuzzy numbers of Table 2 CFCS method is used and the final crisp value of one evaluator is shown in Table 3.

Table 3: Crisp value

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| C1 | 1 | 0.339 | 3.016 | 3.988 | 3.016 | 2.045 | 0.541 |
| C2 | 3.016 | 1 | 4.959 | 5.930 | 3.988 | 3.016 | 2.045 |
| C3 | 0.339 | 0.200 | 1 | 3.016 | 0.541 | 0.251 | 0.200 |
| C4 | 0.251 | 0.167 | 0.339 | 1 | 0.541 | 0.541 | 0.251 |
| C5 | 0.339 | 0.251 | 2.045 | 2.045 | 1 | 0.541 | 0.339 |
| C6 | 0.541 | 0.339 | 3.988 | 2.045 | 2.045 | 1 | 0.251 |
| C7 | 2.045 | 2.045 | 4.959 | 3.988 | 3.016 | 3.988 | 1 |

***Step 6***: *Calculate Integrated matrix values, weights and final ranking*:

When all seven evaluators' judgments are defuzzified and passed the consistency test, firstly Equations (14-15) are applied to calculate integrated crisp matrix. Then, in the final step, Equation (16) is applied for computing the final weights of criteria in level 2 of Hierarchy. Table 4 shows the aggregate crisp judgment matrix and weights of criteria in Level 2.

Table 4: Aggregate crisp judgment matrix with respect to Level 2 for seven experts

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | **Geometric Mean** | Weights (Ranking) |
|---|---|---|---|---|---|---|---|---|---|
| C1 | 1 | 0.328 | 3.624 | 4.206 | 3.174 | 2.158 | 0.491 | 1.4967 | **0.1576 (3)** |
| C2 | 3.106 | 1 | 5.205 | 5.478 | 3.672 | 3.529 | 1.834 | 2.9835 | **0.3142 (1)** |
| C3 | 0.278 | 0.190 | 1 | 1.484 | 0.609 | 0.315 | 0.292 | 0.4603 | **0.0485 (6)** |
| C4 | 0.237 | 0.181 | 0.698 | 1 | 0.641 | 0.386 | 0.274 | 0.412 | **0.0434 (7)** |
| C5 | 0.320 | 0.274 | 1.756 | 1.648 | 1 | 0.761 | 0.276 | 0.658 | **0.0693 (5)** |
| C6 | 0.505 | 0.286 | 3.227 | 2.691 | 1.339 | 1 | 0.301 | 0.9071 | **0.0955 (4)** |
| C7 | 2.206 | 2.206 | 3.459 | 3.672 | 3.639 | 3.360 | 1 | 2.5774 | **0.2715 (2)** |

As a result of the calculations based on Table 4, the weights of seven criteria of level 2 are 0.1576, 0.3142, 0.0485, 0.0434, 0.0693, 0.0955 and 0.2715, respectively. For sub-criteria in level 3 and alternatives in level 4, step 2 to 6 are performed. By multiplying weights of level 2 in level 3 (Sub-criteria), global weight is calculated then transpose of global weight matrix is multiplied to weights of alternatives matrix. Finally, global alternative weights are calculated and final ranking is obtained. The calculated weights of the whole hierarchical structure are summarized in Table 5. According to the obtained results, the forth alternative (ISP4) has the highest weight and is the most proper information system project according to the experts' judgment.

Table 5: summaries of results

| Criteria | Weights for level 2 | Sub-Criteria | Weights for level 2 | global Weight | Local Weights of Alternatives | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | ISP1 | ISP2 | ISP3 | ISP4 | ISP5 |
| C1 | 0.158 | S1 | 1 | 0.158 | 0.145 | 0.171 | 0.239 | 0.257 | 0.188 |
| C2 | 0.314 | S2 | 0.77 | 0.242 | 0.221 | 0.103 | 0.110 | 0.345 | 0.221 |
| C2 | 0.314 | S3 | 0.23 | 0.072 | 0.367 | 0.158 | 0.152 | 0.211 | 0.112 |
| C3 | 0.049 | S4 | 1 | 0.049 | 0.230 | 0.125 | 0.138 | 0.337 | 0.170 |
| C4 | 0.043 | S5 | 0.62 | 0.027 | 0.114 | 0.223 | 0.365 | 0.114 | 0.184 |
| C4 | 0.043 | S6 | 0.38 | 0.016 | 0.163 | 0.199 | 0.256 | 0.150 | 0.232 |
| C5 | 0.069 | S7 | 1 | 0.069 | 0.194 | 0.252 | 0.189 | 0.174 | 0.191 |
| C6 | 0.096 | S8 | 0.804 | 0.077 | 0.130 | 0.125 | 0.245 | 0.245 | 0.255 |
| C6 | 0.096 | S9 | 0.196 | 0.019 | 0.115 | 0.245 | 0.340 | 0.157 | 0.143 |
| C7 | 0.272 | S10 | 1 | 0.272 | 0.125 | 0.226 | 0.265 | 0.169 | 0.216 |

$$\begin{bmatrix}0.158 & 0.314 & \dots & 0.272\end{bmatrix}_{1\times 10} \times \begin{bmatrix}0.145 & 0.171 & 0.188\\ 0.221 & 0.103 & 0.221\\ \vdots & \vdots\ \ddots & \vdots\\ 0.125 & 0.226 & 0.216\end{bmatrix}_{10\times 5} = \begin{matrix} & ISP1 & ISP2 & ISP3 & ISP4 & ISP5 \\ [ & 0.1793 & 0.1716 & 0.2062 & 0.2408 & 0.2023\ ]\end{matrix} \quad (18)$$

## 4. Conclusion

In this paper, a structured methodology for evaluation and selecting IS outsourcings based on fuzzy analytical hierarchy process has been proposed as multi criteria decision-making tools. Also, This paper presents a simple approach in the difficult situations to overcome this problem in the fuzzy setting. Clearly, the proposed model is capable of solving IS outsourcing decision problem with great flexibility and it consequently demonstrates efficient ranking of alternatives. For the extension of this work, other fuzzy AHP methods for selecting IT outsourcing can be used. In addition, various methods of multi-criteria evaluation such as TOPSIS and Data Envelopment Analysis (DEA), and outranking methods like ELECTRE, PROMETHEE, etc. in the fuzzy environment can be applied.

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