Topsis Method for Solving Fuzzy Game Problem Using Octagonal Fuzzy Numbers

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Abstract— In this paper, two person zero sum game has been considered with imprecise values in payoff matrix. All the imprecise values are assumed to be triangular fuzzy numbers, trapezoidal fuzzy numbers and Octagonal Fuzzy Numbers. In this paper, TOPSIS procedure has been used to find the best strategy for the players when the payoffs are Triangular, Trapezoidal and Octagonal Fuzzy Numbers. This method can be used when the relative importance of strategies are not the same that is weights are assigned to the strategies.

Keywords—TOPSIS method, Octagonal fuzzy numbers, Maximin Minmax Principle, Saddle point

I. INTRODUCTION

In 1928, John Von Neumann introduced the concept of game theory but OskarMorgenstern [3] along with John Von Neumann published a article ‘Theory of games and economic Behavior’ in 1944 which was considered as the evolution of modern Game theory. One of the basic problems in the game theory is the two player zero sum game. The two-person zero-sum games are games with only two players where a gain of one player equals a loss to the other (the sum of payoffs of the two players is zero) for any choice of the strategies. The resulting gain can be represented in the form of a matrix, called the payoff matrix of a game. The two players are referred as Player I and Player II.

An optimal solution of a two person zero sum game is obtained using minimax-maxmin principle, according to which player I (whose strategies are represented by rows) selects the strategy which maximizes his minimum gain, the minimum is taken over all the strategies of player II. Similarly player II selects his strategy which minimizes his maximum losses. If the maxmin value equals the minimax value, then the game is said to have a saddle point and the corresponding strategies which give the saddle point are called optimal strategies. The amount of payoff at an equilibrium point is called the game value.

When we apply the Game theory to model some real life competitive situations we come across uncertain or imprecise data. To handle uncertain or imprecise data, we use fuzzy theory[10,11] and model the problems as game with fuzzy payoffs.

TOPSIS was initially presented by Hwang and Yoon and Lai et al[1,2]. In this paper, TOPSIS procedure has been used to find the best strategy for the players when the payoffs are Triangular, Trapezoidal and Octagonal Fuzzy Numbers. This method can be used when the relative importance of strategies are not the same that is weights are assigned to the strategies.

II. PRELIMINARIES

2.1 Triangular Fuzzy Numbers

A fuzzy number $\tilde{A} = (a_1, a_2, a_3)$ is said to be triangular fuzzy number if its membership function is given by,

$$
\mu_{\tilde{A}}(x) = \begin{cases} 
0 & \text{for } x < a_1 \\
\frac{x-a_1}{(a_2-a_1)} & \text{for } a_1 \leq x \leq a_2 \\
\frac{a_3-x}{(a_3-a_2)} & \text{for } a_2 \leq x \leq a_3 \\
0 & \text{for } x > a_3 
\end{cases}
$$

where $a_1 \leq a_2 \leq a_3$ are real numbers

2.2 Trapezoidal Fuzzy Numbers

A fuzzy number $\tilde{A} = (a_1, a_2, a_3, a_4)$ is said to be trapezoidal fuzzy number if its membership function is given by, where $a_1 \leq a_2 \leq a_3 \leq a_4$ are real numbers

$$
\mu_{\tilde{A}}(x) = \begin{cases} 
0 & \text{for } x < a_1 \\
\frac{x-a_1}{(a_2-a_1)} & \text{for } a_1 \leq x \leq a_2 \\
1 & \text{for } a_2 \leq x \leq a_3 \\
\frac{(a_4-x)}{(a_4-a_3)} & \text{for } a_3 \leq x \leq a_4 \\
0 & \text{for } x > a_4 
\end{cases}
$$

2.3 Octagonal Fuzzy Numbers

A fuzzy number $\tilde{A}$ is a normal octagonal fuzzy number denoted by $(a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8)$ where $a_1 \leq a_2 \leq a_3 \leq a_4 \leq a_5 \leq a_6 \leq a_7 \leq a_8$ are real numbers and its membership function $\mu_{\tilde{A}}(x)$ is given below[5]
III. TOPSIS METHOD FOR SOLVING FUZZY GAME PROBLEM

Consider a fuzzy game problem whose payoff matrix is expressed as follows:

\[
\begin{bmatrix}
\tilde{a}_{11} & \tilde{a}_{12} & \ldots & \tilde{a}_{1n} \\
\tilde{a}_{21} & \tilde{a}_{22} & \ldots & \tilde{a}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\tilde{a}_{m1} & \tilde{a}_{m2} & \ldots & \tilde{a}_{mn}
\end{bmatrix}
\]

where each \(\tilde{a}_{ij}\) is a fuzzy number that may be triangular, trapezoidal or octagonal.

Step (1) Calculate the Normalized Payoff matrix. The normalized value \(\tilde{n}_{ij}\) is calculated as

\[
\tilde{n}_{ij} = \frac{a_{ij}}{\sqrt{\sum_{j=1}^{m}(a_{ij})^2}}, \quad j = 1, 2, \ldots, n
\]

where \(a_{ij}\) is the distance of the fuzzy number from the crisp number 0.

Step (2) Calculate the Weighted Normalized payoff matrix \(\tilde{v}_{ij}\).

If \(w\) is a crisp value,

\[
\tilde{v}_{ij} = w_j \times \tilde{n}_{ij}, \quad i = 1, 2, \ldots, m, j = 1, 2, \ldots, n
\]

where \(w_j\) is the weight of the strategies of players and \(\sum_{j=1}^{n} w_j = 1\).

If \(w\) is a fuzzy value:

\[
\tilde{v}_{ij} = s(\tilde{w}_j, 0) \times \tilde{n}_{ij}, \quad i = 1, 2, \ldots, m, j = 1, 2, \ldots, n
\]

Step (3) Find the crisp value matrix \(A\) corresponding to \(\tilde{A}\) using \(s(\tilde{v}_{ij}, 0)\)

Determine the Positive Ideal and Negative Ideal Solutions of Player I and Player II.

Step (4) The Positive Ideal and Negative Ideal Solutions of Player I respectively are

\[
A^+_i = \{v^+_1, v^+_2, \ldots, v^+_m\}
\]

where \(v^+_i = \{\text{Max}_j\{s(\tilde{v}_{ij}, 0)\}, i = 1, 2, \ldots, m\}

\[
A^-_i = \{v^-_1, v^-_2, \ldots, v^-_m\}
\]

where \(v^-_i = \{\text{Min}_j\{s(\tilde{v}_{ij}, 0)\}, i = 1, 2, \ldots, m\}

The Positive Ideal and Negative Ideal Solutions of Player II respectively are

\[
A^+_i = \{v'^+_1, v'^+_2, \ldots, v'^+_m\}
\]

where \(v'^+_j = \{\text{Max}_i\{s(\tilde{v}_{ij}, 0)\}, j = 1, 2, \ldots, n\}

\[
A^-_i = \{v'^-_1, v'^-_2, \ldots, v'^-_n\}
\]

where \(v'^-_j = \{\text{Min}_i\{s(\tilde{v}_{ij}, 0)\}, j = 1, 2, \ldots, n\}

Step (5) Calculate the Separation Measures using Euclidean distance.

The Separation of each strategy of player I from the Positive-ideal solution is

\[
d^+_i = \sqrt{\sum_{j=1}^{m}(v^+_i - s(\tilde{v}_{ij}, 0))^2}, i = 1, 2, \ldots, m
\]

The Separation of each strategy of player I from the Negative-ideal solution is

\[
d^-_i = \sqrt{\sum_{j=1}^{m}(v^-_i - s(\tilde{v}_{ij}, 0))^2}, i = 1, 2, \ldots, m
\]

The Separation of each strategy of player II from the Positive-ideal solution is

\[
d^+_j = \sqrt{\sum_{i=1}^{n}(v'^+_j - s(\tilde{v}_{ij}, 0))^2}, j = 1, 2, \ldots, n
\]

The Separation of each strategy of player II from the Negative-ideal solution is

\[
d^-_j = \sqrt{\sum_{i=1}^{n}(v'^-_j - s(\tilde{v}_{ij}, 0))^2}, j = 1, 2, \ldots, n
\]

Step (6) Calculate the relative closeness to ideal solution.

The relative closeness distance of the strategies \(A_i\) with respect to maximum gain is defined as
The relative closeness distance of the strategies with respect to minimum loss is defined as

\[ cl^+_i = \frac{d^+_i}{d^+_i + d^-_i}, i = 1,2, ..., m \]

\[ cl^-_j = \frac{d^-_j}{d^-_j + d^+_j}, j = 1,2, ..., n \]

**Step (7)** The strategy for which the closeness distance is least will be the best strategy

IV. **Numerical Example**

Consider the two health insurance companies, Moon health insurance and National health insurance. Both the companies have three types of policies namely individual health insurance policies, family floater health insurance policies, Surgery & critical illness insurance plans. The following pay off matrix gives the gain for Moon health insurance company when they choose their different types of policies along with the national insurance company:

Consider the problem as in example in which the three types of policies are not given equal importance. That is, weights are assigned to them

1) Individual health insurance policies are given weight 0.5
2) Family floater health insurance policies are given weight 0.3
3) Surgery & critical illness insurance plans are given weight 0.2

**Pay off matrix with pay offs as Octagonal Fuzzy numbers**

Consider the payoff matrix

**National Health insurance (player II)**

<table>
<thead>
<tr>
<th>Moon health insurance (player I)</th>
<th>2, 4, 5, 6, 7, 8, 9, 11</th>
<th>2, 3, 4, 5, 6, 7, 8, 9</th>
<th>1, 3, 4, 5, 7, 8, 9, 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2, 4, 5, 6, 7, 8, 9, 11)</td>
<td>(2, 3, 4, 5, 6, 7, 8, 9)</td>
<td>(1, 3, 4, 5, 7, 8, 9, 11)</td>
<td></td>
</tr>
<tr>
<td>(−1, 0, 1, 2, 3, 4, 5, 6)</td>
<td>(−3, −2, −1, 0, 1, 2, 3, 4)</td>
<td>(−3, −2, 0, 2, 3, 5, 7, 8)</td>
<td></td>
</tr>
<tr>
<td>(−2, −1, 0, 2, 3, 5, 6, 7)</td>
<td>(−6, −5, −4, −3, 0, 1, 2, 3)</td>
<td>(−1, 0, 1, 3, 5, 7, 8, 9)</td>
<td></td>
</tr>
</tbody>
</table>

**Step (1)** The Normalized Decision matrix is

\[ \tilde{n}_{ij} = \frac{\tilde{a}_{ij}}{\sqrt{\sum_{i=1}^{3}(s(\tilde{a}_{ij}, 0))^2}}, j = 1,2,3 \text{ where } s(\tilde{a}_{ij}, 0) = \frac{1}{4}[(a_1 + a_2 + a_7 + a_8)k + (a_3 + a_4 + a_5 + a_6)(1-k)] \]

**Player I**

| (0.2, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.1) | (0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9) | (0.1, 0.3, 0.4, 0.5, 0.6, 0.7, 0.9, 1.1) |
| (−0.3, 0.0, 0.3, 0.6, 0.9, 1.2, 1.5, 1.8) | (−0.9, −0.6, −0.3, 0.3, 0.6, 0.9, 1.2) | (−0.9, −0.6, 0.0, 0.9, 1.5, 1.8, 2.1) |
| (−0.4, −0.2, 0.0, 0.2, 0.6, 1.1, 1.1, 1.3) | (−1.1, −1.0, −0.8, −0.6, 0.2, 0.4, 0.6) | (−0.2, 0.0, 0.4, 0.6, 1.3, 1.5, 1.7) |

**Step (2)** The weighted normalized decision matrix with \( w = (0.5, 0.3, 0.2) \) is

**Player II**

| (0.1, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.55) | (0.06, 0.09, 0.12, 0.15, 0.18, 0.21, 0.24, 0.27) | (0.02, 0.06, 0.08, 0.1, 0.12, 0.14, 0.18, 0.1) |
| (−0.15, 0.05, 0.3, 0.45, 0.6, 0.75, 0.9) | (−0.27, −0.18, −0.09, 0.09, 0.18, 0.27, 0.36) | (−0.18, −0.12, 0.12, 0.18, 0.36, 0.42) |
| (−0.2, −0.1, 0.0, 0.3, 0.5, 0.55, 0.65) | (−0.33, −0.3, −0.24, −0.18, 0.06, 0.12, 0.18) | (−0.04, 0.008, 0.122, 0.26, 0.30, 0.16, 0.38) |
Step (3)

Resultant Crisp value matrix is

<table>
<thead>
<tr>
<th>Player I</th>
<th>Player II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.33, 0.17, 0.11)</td>
<td>(0.36, 0.05, 0.14)</td>
</tr>
</tbody>
</table>

Step (4)

Determine the Maximum of Player I&II (Positive Ideal ) and Minimum of Player I&II (Negative Ideal )

\[ A^+_{I} = \{v^+_1, v^+_2, v^+_3\} = \{0.33, 0.38, 0.23\} \]
\[ A^+_{II} = \{v'^+_1, v'^+_2, v'^+_3\} = \{0.38, 0.17, 0.16\} \]
\[ A^-_{I} = \{v^-_1, v^-_2, v^-_3\} = \{0.11, 0.05, -0.09\} \]
\[ A^-_{II} = \{v'^-_1, v'^-_2, v'^-_3\} = \{0.23, -0.09, 0.11\} \]

Step (5)

Calculate the Separation measures for Player I and Player II

Table : 1

<table>
<thead>
<tr>
<th>Player I</th>
<th>Player II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(d^+)</td>
<td>(d^-)</td>
</tr>
<tr>
<td>0</td>
<td>0.51</td>
</tr>
<tr>
<td>0.49</td>
<td>0.06</td>
</tr>
<tr>
<td>0.33</td>
<td>0.27</td>
</tr>
<tr>
<td>0.07</td>
<td>0.12</td>
</tr>
<tr>
<td>0.3</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Step (6)

Calculate the relative closeness distance of strategies with maximum gain for Player I and minimum loss of player II

Table : 2

<table>
<thead>
<tr>
<th>Strategies of Player I</th>
<th>Closeness distance of strategies with maximum gain for Player I</th>
<th>Strategies of Player II</th>
<th>Closeness distance of strategies with minimum loss of Player II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A_1)</td>
<td>0</td>
<td>(B_1)</td>
<td>0.8</td>
</tr>
<tr>
<td>(A_2)</td>
<td>0.89</td>
<td>(B_2)</td>
<td>0.64</td>
</tr>
<tr>
<td>(A_3)</td>
<td>0.55</td>
<td>(B_3)</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Step (7)

Since the closeness coefficient for \(A_1\) and \(B_3\) are least, the best strategies of player I and II are \(A_1\) and \(B_3\) respectively.

Pay off matrix with pay offs as Trapezoidal Fuzzy numbers
For the above problem if \(k=1\), then the payoffs reduce to trapezoidal fuzzy numbers and the payoff matrix is given by

<table>
<thead>
<tr>
<th>Player I</th>
<th>Player II</th>
</tr>
</thead>
<tbody>
<tr>
<td>((3.6, 7.11), (2.5, 6.9), (1.5, 7.11))</td>
<td>((-1.2, 3.6), (-3.0, 1.4), (-3.2, 3.8))</td>
</tr>
<tr>
<td>((-2.2, 3.7), (-6, -3.0), (-1.3, 5.9))</td>
<td>((-2.0, 6.0), (6.0, 9.2), (6.0, 9.2))</td>
</tr>
</tbody>
</table>

Step (1) The Normalized Decision matrix is

\[ \bar{a}_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{n}(a_{kj})^2}}, \quad j = 1, 2, 3 \]

where \(s(\bar{a}_{ij}, 0) = \frac{a_{ij} + a_{j+} + a_{j-}}{4} \)

\[ \begin{pmatrix} (0.2, 0.6, 0.1, 1.1) & (0.2, 0.5, 0.6, 0.9) & (0.1, 0.5, 0.6, 1) \\ (0.2, 0.5, 0.6, 1.8) & (0.2, 0.5, 0.6, 1.2) & (0.2, 0.5, 0.6, 1.8) \\ (0.2, 0.5, 0.6, 1.5) & (0.2, 0.5, 0.6, 1.3) & (0.2, 0.5, 0.6, 1.9) \end{pmatrix} \]

Step (2)

Calculate the weighted normalized decision matrix with \(w = (0.5, 0.3, 0.2)\) is

\[ \begin{pmatrix} (0.1, 0.3, 0.4, 0.6) & (0.1, 0.2, 0.2, 0.3) & (0.2, 0.1, 0.1, 0.2) \\ (0.2, 0.3, 0.5, 0.9) & (0.2, 0.3, 0.1, 0.4) & (0.2, 0.1, 0.2, 0.4) \\ (0.2, 0.1, 0.3, 0.8) & (0.4, 0.2, 0.0, 0.2) & (0.4, 0.1, 0.2, 0.4) \end{pmatrix} \]

Step (3)

Resultant Crisp value matrix is

<table>
<thead>
<tr>
<th>Player I</th>
<th>Player II</th>
</tr>
</thead>
<tbody>
<tr>
<td>((0.35, 0.2, 0.11)) &amp; ((0.38, 0.05, 0.13))</td>
<td></td>
</tr>
<tr>
<td>((0.25, -0.1, 0.17))</td>
<td>((0.25))</td>
</tr>
</tbody>
</table>

Step (4)

Determine the Maximum of Player I & II (Positive Ideal) and Minimum of Player I & II (Negative Ideal)

\[ A^+_{I} = \{v^+_1, v^+_2, v^+_3\} = \{0.35, 0.38, 0.25\} \]
\[ A^+_{II} = \{v'^+_1, v'^+_2, v'^+_3\} = \{0.38, 0.2, 0.17\} \]
\[ A^-_{I} = \{v^-_1, v^-_2, v^-_3\} = \{0.11, 0.05, -0.1\} \]
Step (5) Calculate the Separation measures for Player I and Player II

Table 3
Table showing the separation measures for Player I and Player II in TOPSIS procedure with trapezoidal payoffs

<table>
<thead>
<tr>
<th>Player I</th>
<th>Player II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d^+$</td>
<td>$d^-$</td>
</tr>
<tr>
<td>0.54</td>
<td>0.07</td>
</tr>
<tr>
<td>0.09</td>
<td>0.16</td>
</tr>
<tr>
<td>0.28</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Step (6) Calculate the relative closeness distance of strategies with maximum gain for Player I and minimum loss of player II

Table 4
Table showing the closeness distance of strategies with maximum gain for Player I and minimum loss of Player II in TOPSIS procedure with trapezoidal payoffs

<table>
<thead>
<tr>
<th>Strategies of Player I</th>
<th>Closeness distance of strategies with maximum gain for Player I</th>
<th>Strategies of Player II</th>
<th>Closeness distance of strategies with minimum loss of Player II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_1</td>
<td>0</td>
<td>B_1</td>
<td>0.82</td>
</tr>
<tr>
<td>A_2</td>
<td>0.85</td>
<td>B_2</td>
<td>0.56</td>
</tr>
<tr>
<td>A_3</td>
<td>0.56</td>
<td>B_3</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Step (7) Since the closeness coefficient for $A_1$ and $B_3$ are least, the best strategies of player I and II are $A_1$ and $B_3$ respectively.

Pay off matrix with pay offs as triangular Fuzzy numbers

For the above game problem with pay offs as trapezoidal fuzzy numbers, if we take $a_2 = a_3 = \frac{a_1 + a_2 + a_3}{2}$ the pay offs become triangular fuzzy numbers and the pay off matrix is given by

Player II

\[
\begin{pmatrix}
0.25, -0.1, 0.11 \\
(2,6,5,11) & (2,5,5,9) & (1,6,11) \\
(2,2,5,7) & (6,1,5,3) & (1,4,9)
\end{pmatrix}
\]

Player I

\[
\begin{pmatrix}
(0.2,0.6,1.1) & (0.2,0.5,0.9) & (0.1,0.6,1.1) \\
(0.3,0.7,1.8) & (0.9,0.1,1.2) & (0.9,0.7,2.1) \\
(0.4,0.5,1.4) & (1.2,0.3,0.6) & (0.2,0.8,1.9)
\end{pmatrix}
\]

Step (1) The Normalized pay off matrix is

\[\hat{n}_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{n} (\hat{a}_{ij})^2}}, j = 1,2,3\]

where $s(\hat{a}_{ij}, 0) = \frac{a_{1i} + a_{2i} + a_{3i}}{4}$

Step (2) The weighted normalized payoff matrix with $w = 0.5, 0.3, 0.2$ is

Player II

\[
\begin{pmatrix}
0.6,0.15,0.27 & (0.2,0.18,0.22) \\
(0.15,0.35,0.9) & (0.27,0.03,0.36) & (0.18,0.14,0.42) \\
(0.2,0.25,0.7) & (0.36,0.09,0.18) & (0.04,0.16,0.38)
\end{pmatrix}
\]

Step (3) Resultant Crisp value matrix is

Player II

\[
\begin{pmatrix}
0.31 & 0.16 & 0.15 \\
0.36 & 0.04 & 0.13 \\
0.25 & 0.09 & 0.17
\end{pmatrix}
\]

Step (4) Determine the Maximum of Player I&II (Positive Ideal ) and Minimum of Player I&II (Negative Ideal )

\[
\begin{align*}
A_1^+ &= \{v_1^+, v_2^+, v_3^+\} = \{0.31, 0.36, 0.25\} \\
A_2^+ &= \{v_1^+, v_2^+, v_3^+\} = \{0.36, 0.16, 0.17\} \\
A_1^- &= \{v_1^-, v_2^-, v_3^-\} = \{0.15, 0.04, -0.09\} \\
A_2^- &= \{v_1^-, v_2^-, v_3^-\} = \{0.25, -0.09, 0.13\}
\end{align*}
\]

Step (5) Calculate the Separation measures for Player I and Player II

Table 5
Table showing the separation measures for Player I and Player II in TOPSIS procedure with triangular payoffs

<table>
<thead>
<tr>
<th>Player I</th>
<th>Player II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d^+$</td>
<td>$d^-$</td>
</tr>
<tr>
<td>0.48</td>
<td>0.05</td>
</tr>
<tr>
<td>0.31</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Step (6) Calculate the relative closeness distance of strategies with maximum gain for Player I and minimum loss of Player II

Table 6
Table showing the closeness distance of strategies with maximum gain for Player I and minimum loss of Player II in TOPSIS procedure with triangular payoffs

<table>
<thead>
<tr>
<th>Strategies of Player I</th>
<th>Closeness distance of strategies with maximum gain for Player I</th>
<th>Strategies of Player II</th>
<th>Closeness distance of strategies with minimum loss of Player II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0</td>
<td>B1</td>
<td>0.76</td>
</tr>
<tr>
<td>A2</td>
<td>0.9</td>
<td>B2</td>
<td>0.58</td>
</tr>
<tr>
<td>A3</td>
<td>0.53</td>
<td>B3</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Step (7) Since the closeness coefficient for A1 and B3 are least, the best strategies of player I and II are A1 and B3 respectively.

V. CONCLUSION

In this paper, we have considered two person zero sum game with pay offs as triangular, trapezoidal and Octagonal Fuzzy Numbers. TOPSIS (Technique for order preference by similarity to ideal solution) procedure is proposed when the relative importance of strategies are not the same that is weights are assigned to the strategies.

We explain the proposed method through a numerical example in which k value for octagonal fuzzy number is taken as 0.5 and the weights for strategies are taken as 0.5,0.3 and 0.2. For different weights we will get different solution.

REFERENCES