Approach of VIKOR Method under MCDM Using Fuzzy Numbers

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ABSTRACT

Decision making is a difficult task because of the environment's ambiguity and imprecision. Such issues can be resolved by applying the ideas of fuzzy sets by using modified VIKOR method. The aim of this paper is to select a suitable crop for all climatic changes. The application of fuzzy decision making problem is explained through a numerical example to find the best crop.

Keywords

MCDM, VIKOR Method, Fuzzy Sets, Fuzzy Decision Making Problems.

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INTRODUCTION

Multi Criteria Decision Making (MCDM) is a key technique in expert systems and operations research that involves a variety of decision alternatives and criteria. It entails designing, planning, and solving decision issues using a variety of criteria. Due to its capacity to increase the quality of decisions through a more explicit, logical, and effective procedure. When compared to conventional approaches, the use of MCDM is gaining favour quickly. Researchers have created a variety of MCDM methods throughout the years to address a variety of discrete challenges in many fields. In order to handle decision-making difficulties, this method is used to address the crucial requirement of identifying the qualified alternatives from a collection of options based on the selected criteria. Additionally, MCDM methodologies are typically split into two primary approaches, each of which offers criterion weighting and/or alternative ranking. This Method of weighting and ranking method should, however, be used with a decision-making process because problems and challenges are frequently complicated. Fuzzy sets were introduced independently by Lotfi A.Zadeh in 1965 as an extension of the classical notion of set. Fuzzy number have been introduced by Zadeh in order to deal with imprecise numerical quantities in a practical way.

2. PRELIMINARIES

2.1. Fuzzy Set

A fuzzy set A defined on X can be expressed as a collection of ordered pairs if X is a discourse universe and x is a specific element of X.

$$A = \{(x, \mu_A(x)), x \in X\}$$

2.2. Normalized Fuzzy Set

A fuzzy set is called normalized when at least one of its elements attain the maximum possible membership grade. That is, the membership grade range is in the closed interval between [0, 1] where at least one element must have a membership grade of 1.

2.3. Fuzzy Number

It is a fuzzy set it satisfies the following conditions:

(i) Convex fuzzy set.

(ii) Normalized fuzzy set.

(iii) Its membership function is piecewise continuous.

(iv) It is defined in the real number.

2.4. Triangular Fuzzy Number (TFN)

A fuzzy number $A = (a, b, c)$ is said to be Triangular fuzzy number if its membership function is given by

$$\mu_A(X) = \begin{cases} 0 & , \quad x \le a \\ \frac{x-a}{b-a} & , \quad a \le x \le b \\ \frac{c-x}{c-b} & , \quad b \le x \le c \\ 0 & , \quad x \ge c \end{cases}$$

Where a, b, c are real numbers .

2.5. Trapezoidal Fuzzy Number

A fuzzy number $A = (a, b, c, d)$ is said to be Trapezoidal fuzzy number if its membership function is given by

$$\mu_A(X) = \begin{cases} 0 & , \quad x < a \\ \frac{x-a}{b-a} & , \quad a \le x \le b \\ 1 & , \quad b \le x \le c \\ \frac{d-x}{d-c} & , \quad c \le x \le d \\ 0 & , \quad x > d \end{cases}$$

Where a, b, c, d are real numbers.

2.6. Pentagonal fuzzy number

A fuzzy number $A = (a, b, c, d, e)$ is said to be Pentagonal fuzzy number if its membership function is given by

$$\boldsymbol{\mu_A}(X) = \begin{cases} 0 & , \quad x < a, e \le x \\ \frac{x-a}{b-a} & , \quad a \le x \le b \\ \frac{x-b}{c-b} & , \quad b \le x \le c \\ 1 & , \quad x = c \\ \frac{d-x}{d-c} & , \quad c \le x \le d \\ \frac{e-x}{e-d} & , \quad e \le x \le d \end{cases}$$

Where a, b, c, d, e are real numbers .

2.7. Hexagonal fuzzy number

A fuzzy number$A = (a, b\ c, d, e, f\ )$ is said to be Hexagonal fuzzy number if its membership function is given by

$$\mu_A(X) = \begin{cases} 0 & , \ x < a \\ \left(\frac{1}{2}\right)\left(\frac{x-a}{b-a}\right) & , \ a \le x \le b \\ \frac{1}{2} + \left(\frac{1}{2}\right)\left(\frac{x-b}{c-b}\right) & , \ b \le x \le c \\ 1 & , \ c \le x \le d \\ 1 - \left(\frac{1}{2}\right)\left(\frac{x-d}{e-d}\right) & , \ d \le x \le e \\ \left(\frac{1}{2}\right)\left(\frac{f-x}{f-e}\right) & , \ e \le x \le f \\ 0 & , \ x > e \end{cases}$$

Where a, b, c, d, e, f are real numbers .

2.8. Heptagonal fuzzy number

A fuzzy number $A = (a, b, c, d, e, f, g)$ is said to be Heptagonal fuzzy number if its membership function is given by

$$\mu_A(X) = \begin{cases} \left(\frac{1}{2}\right)\left(\frac{x-a}{b-a}\right) & , \quad a \le x \le b \\ \frac{1}{2} & , \quad b \le x \le c \\ \left(\frac{1}{2}\right)\left(\frac{x-d}{d-c}\right) + 1 & , \quad c \le x \le d \\ \left(\frac{1}{2}\right)\left(\frac{d-x}{e-d}\right) + 1 & , \quad d \le x \le e \\ \left(\frac{1}{2}\right) & , \quad e \le x \le f \\ \left(\frac{1}{2}\right)\left(\frac{g-x}{g-f}\right) & , \quad f \le x \le g \\ 0 & , \quad otherwise \end{cases}$$

Where a, b, c, d, e, f, g are real numbers .

3. VIKOR METHOD

Opricovic and Tzeng suggested VIKOR method, a compromise ranking approach, as a suitable means of ranking technique under MCDM problems. This technique was created to address discrete choice issues and improve complex systems using several criteria that are incommensurable and incompatible. When a decision-maker is unable to convey their desire for a compromise solution, this is a useful decision-making methodology.

3.1. PROCEDURE:

Step 1: Determination of Best and Worst value is given by

$$\left.\begin{array}{c} f_j^* = Max\left(f_{ij}\right) \\ f_j^- = Min\left(f_{ij}\right) \end{array}\right\} \quad \text{---------------} \quad \textbf{(1)}$$

Step 2: Normalization of S_j *and* R_j are given by

$$\left.\begin{array}{c} S_j = \sum_{j=1}^{n} w_j \left[\frac{f_j^* - f_{ij}}{f_j^* - f_j^-}\right]; i = 1 \; to \; m. \\ R_j = max_j \left[w_j \frac{f_j^* - f_{ij}}{f_j^* - f_j^-}\right] \; ; i = 1 \; to \; m \,, \;\; j = 1 \; to \; n. \end{array}\right\} \text{--------------} \; \textbf{(2)}$$

Step 3: Computation of Q_j for group utility function

$$\left. Q_j = v\left(\frac{S_j - S^+}{S^+ - S^-}\right) + (1 - v)\left(\frac{R_j - R^+}{R^- - R^+}\right)\right\} \text{---------------} \; \textbf{(3)}$$

Step 4:

Sorting of R_j, S_j *and* Q_j are made from their minimum value. Hence the three ranking list is obtained.

Step 5:

Case 1: $Q(a(2)) - Q(a(1)) \geq D_Q$

Case 2: Choice of random acceptance stability, Where Q_j is best choice from S *and* R with $v \geq 0.5$.

4. LINGUISTIC VARIABLES

A linguistic variable X is a variable whose values are natural or artificial language words or sentences. If 'age' is viewed as a linguistic variable, for example, its term set, (X) , or the set of its linguistic values, could be

$$\tau(age) = Very\ Very\ Young, Very\ Young, Medium\ Young, \ldots$$

Where each term in $\tau(age)$ represents a description for a fuzzy subset of a discourse universe.

5. NUMERICAL EXAMPLES

By using different fuzzy numbers, the farmer (decision maker) has to find the best crop for all climatic changes using the VIKOR method.

EXAMPLE 1: Using Triangular Fuzzy Number

Linguistic Variables	**Triangular fuzzy number**
Very Very low[1,5]	(1, 2, 4)
Low[6,10]	(6, 8, 9)
Medium[11,15]	(12,13, 15)
Very important[16,20]	(17,19 , 20)
Very high important[21,25]	(21, 22, 24)

Criteria C'/ Alternative A'	**C'_1 (Plough)**	**C'_2 (Feed quality)**	**C'_3 (Water)**	**C'_4 (Fertilizer)**
A'_1	Very Important	Medium	Low	Medium

A'_2	Very Important	Low	Medium	Very Very low
A'_3	Medium	Low	Medium	Very high important
A'_4	Very high important	Very Important	Medium	Low

	C'_1	C'_2	C'_3	C'_4
A'_1	(17,19 , 20)	(12,13, 15)	(6, 8, 9)	(12,13, 15)
A'_2	(17,19 , 20)	(6, 8, 9)	(12,13, 15)	(1, 2, 4)
A'_3	(12,13, 15)	(6, 8, 9)	(12,13, 15)	(21, 22, 24)
A'_4	(21, 22, 24)	(17,19 , 20)	(12,13, 15)	(6, 8, 9)

ALGORITHM

Step 1: The Triangular fuzzy number can be defuzzified by using the formula

$$\left(\frac{a+b+c}{3}\right)$$

After defuzzification we get

	C'_1	C'_2	C'_3	C'_4
A'_1	18.7	13.3	7.7	13.3
A'_2	18.7	7.7	13.3	2.3
A'_3	13.3	7.7	13.3	18.7
A'_4	22.3	18.7	13.3	7.7

Step 2:

Find maximum and minimum values of each column from the defuzzification table by using the Equation (1)

	C'_1	C'_2	C'_3	C'_4

A_1'	18.7	13.3	7.7	13.3
A_2'	18.7	7.7	13.3	2.3
A_3'	13.3	7.7	13.3	18.7
A_4'	22.3	18.7	13.3	7.7
$f_j^*(max)$	22.3	18.7	13.3	18.7
$f_j^-(min)$	13.3	7.7	7.7	2.3

Step 3: Calculate the S_j and R_j index for each alternatives by using the Equation (2)

S_j	R_j
0.55	0.14
0.63	0.25
0.5	0.25
0.2	0.2

Step 4:

Calculate Q_j by using the Equation (3) and also find the Ranks for the alternative are given by

Alternative	Q_j	Rank
A_1'	0.254	2
A_2'	1	4
A_3'	0.884	3
A_4'	0.177	1

RESULT

The above table clearly shows that A_4' (Him) has the minimum score value. So, the decision maker has decided to choose the A_4' (Him) as a best crop .

EXAMPLE 2: Using Trapezoidal Fuzzy Number

Linguistic Variables	Trapezoidal fuzzy number
Very Very low [1,5]	(1,3,4,5)
Low[6,10]	(6,7,10,9)
Medium[11,15]	(11,13,15,14)
Very important[16,20]	(17,16,19,20)
Very high important[21,25]	(23,25,21,24)

	C'_1	C'_2	C'_3	C'_4
A'_1	(17,16,19,20)	(11,13,15,14)	(6,7,10,9)	(11,13,15,14)
A'_2	(17,16,19,20)	(6,7,10,9)	(11,13,15,14)	(1,3,4,5)
A'_3	(11,13,15,14)	(6,7,10,9)	(11,13,15,14)	(23,25,21,24)
A'_4	(23,25,21,24)	(17,16,19,20)	(11,13,15,14)	(6,7,10,9)

ALGORITHM

Step 1: The Trapezoidal fuzzy number can be defuzzified by using the formula

$$\left(\frac{2a + 7b + 7c + 2d}{18}\right)$$

After defuzzification we get

	C'_1	C'_2	C'_3	C'_4
A'_1	17.722	13.667	8.278	13.667
A'_2	17.722	8.278	13.667	3.389
A'_3	13.667	8.278	13.667	23.111
A'_4	23.111	17.722	13.667	8.278

Step 2:

Find maximum and minimum values of each column from the defuzzification table by using the Equation (1)

	C_1'	C_2'	C_3'	C_4'
A_1'	17.722	13.667	8.278	13.667
A_2'	17.722	8.278	13.667	3.389
A_3'	13.667	8.278	13.667	23.111
A_4'	23.111	17.722	13.667	8.278
$f_j^*(max)$	23.111	17.722	13.667	23.111
$f_j^-(min)$	13.667	8.278	8.278	3.389

Step 3:

Calculate the S_j and R_j index for each alternatives by using the Equation (2)

S_j	R_j
0.489	0.143
0.643	0.25
0.5	0.25
0.188	0.188

Step 4:

Calculate Q_j by using the Equation (3) and also find the Ranks for the alternative are given by

Alternative	Q_j	Rank
A_1'	0.331	2
A_2'	1	4
A_3'	0.843	3
A_4'	0.211	1

RESULT

The above table clearly shows that A'_4 (Him) has the minimum score value. So, the decision maker has decided to choose the A'_4 (Him) as a best crop .

EXAMPLE 3: Using Pentagonal Fuzzy Number

Linguistic Variables	Pentagonal fuzzy number
Very Very low[1,10]	(2,5,7,8,3)
Low[11,20]	(13,12,16,14,20)
Medium[21,30]	(25,24,26,28,30)
Very important[31,40]	(35,32,38,40,31)
Very high important[41,50]	(45,43,42,44,48)

	C'_1	C'_2	C'_3	C'_4
A'_1	(35,32,38,40,31)	(25,24,26,28,30)	(13,12,16,14,20)	(25,24,26,28,30)
A'_2	(35,32,38,40,31)	(13,12,16,14,20)	(25,24,26,28,30)	(2,5,7,8,3)
A'_3	(25,24,26,28,30)	(13,12,16,14,20)	(25,24,26,28,30)	(45,43,42,44,48)
A'_4	(45,43,42,44,48)	(35,32,38,40,31)	(25,24,26,28,30)	(13,12,16,14,20)

ALGORITHM

Step 1: The Pentagonal fuzzy number can be defuzzified by using the formula

$$\left(\frac{6(a+b+c+d+e)}{15}\right)$$

After defuzzification we get

	C'_1	C'_2	C'_3	C'_4

A_1'	70.4	53.2	30	53.2
A_2'	70.4	30	53.2	10
A_3'	53.2	30	53.2	88.8
A_4'	88.8	70.4	53.2	30

Step 2:

Find maximum and minimum values of each column from the defuzzification table by using the Equation (1)

	C_1'	C_2'	C_3'	C_4'
A_1'	70.4	53.2	30	53.2
A_2'	70.4	30	53.2	10
A_3'	53.2	30	53.2	88.8
A_4'	88.8	70.4	53.2	30
$f_j^*(max)$	88.8	70.4	53.2	88.8
$f_j^-(min)$	53.2	30	30	10

Step 3:

Calculate the S_j and R_j index for each alternatives by using the Equation (2)

S_j	R_j
0.462	0.129
0.629	0.25
0.5	0.25
0.187	0.187

Step 4:

Calculate Q_j by using the Equation (3) and also find the Ranks for the alternative are given by

Alternative	Q_j	Rank
A_1'	0.3106	2
A_2'	1	4
A_3'	0.854	3
A_4'	0.237	1

RESULT

The above table clearly shows that A_4' (Him) has the minimum score value. So, the decision maker has decided to choose the A_4' (Him) as a best crop .

EXAMPLE 4: Hexagonal Fuzzy Number

Linguistic Variables	Hexagonal fuzzy number
Very Very low[1,10]	(1,3,2,5,6,4)
Low[11,20]	(11,15,19,20,14,17)
Medium[21,30]	(24,21,25,28,30,29)
Very important[31,40]	(34,33,36,37,38,40)
Very high important[41,50]	(41,44,45,48,50,47)

	C_1'	C_2'	C_3'	C_4'
A_1'	(34,33,36,37,38,40)	(24,21,25,28,30,29)	(11,15,19,20,14,17)	(24,21,25,28,30,29)
A_2'	(34,33,36,37,38,40)	(11,15,19,20,14,17)	(24,21,25,28,30,29)	(1,3,2,5,6,4)
A_3'	(24,21,25,28,30,29)	(11,15,19,20,14,17)	(24,21,25,28,30,29)	(41,44,45,48,50,47)
A_4'	(41,44,45,48,50,47)	(34,33,36,37,38,40)	(24,21,25,28,30,29)	(11,15,19,20,14,17)

ALGORITHM

Step 1: The Hexagonal fuzzy number can be defuzzified by using the formula

$$\left(\frac{2a + 3b + 4c + 4d + 3e + 2f}{18}\right)$$

After defuzzification we get

	C'_1	C'_2	C'_3	C'_4
A'_1	38.389	27.833	17.389	27.833
A'_2	38.389	17.389	27.833	3.944
A'_3	27.833	17.389	27.833	48.889
A'_4	48.889	38.389	27.833	17.389

Step 2:

Find maximum and minimum values of each column from the defuzzification table by using the Equation (1)

	C'_1	C'_2	C'_3	C'_4
A'_1	38.389	27.833	17.389	27.833
A'_2	38.389	17.389	27.833	3.944
A'_3	27.833	17.389	27.833	48.889
A'_4	48.889	38.389	27.833	17.389
$f_j^*(max)$	38.389	27.833	17.389	27.833
$f_j^-(min)$	38.389	17.389	27.833	3.944

Step 3:

Calculate the S_j and R_j index for each alternatives by using the Equation (2)

S_j	R_j
0.485	0.126
0.625	0.25
0.5	0.25
0.175	0.175

Step 4:

Calculate Q_j by using the Equation (3) and also find the Ranks for the alternative are given by

Alternative	$\boldsymbol{Q_j}$	**Rank**
$\boldsymbol{A'_1}$	0.344	2
$\boldsymbol{A'_2}$	1	4
$\boldsymbol{A'_3}$	0.861	3
$\boldsymbol{A'_4}$	0.199	1

RESULT

The above table clearly shows that A'_4 (Him) has the minimum score value. So, the decision maker has decided to choose the A'_4 (Him) as a best crop.

EXAMPLE 5: Heptagonal Fuzzy Number

Linguistic Variables	**Heptagonal fuzzy number**
Very Very low[1,10]	(1,3,2,5,6,4,7)
Low[11,20]	(11,13,15,19,20,14,17)
Medium[21,30]	(24,27,21,25,28,30,29)
Very important[31,40]	(34,32,33,36,37,38,40)
Very high important[41,50]	(41,49,44,45,48,50,47)

	$\boldsymbol{C'_1}$	$\boldsymbol{C'_2}$	$\boldsymbol{C'_3}$	$\boldsymbol{C'_4}$
$\boldsymbol{A'_1}$	(34,32,33,36,37,38,40)	(24,27,21,25,28,30,29)	(11,13,15,19,20,14,17)	(24,27,21,25,28,30,29)
$\boldsymbol{A'_2}$	(34,32,33,36,37,38,40)	(11,13,15,19,20,14,17)	(24,27,21,25,28,30,29)	(1,3,2,5,6,4,7)

A_3'	(24,27,21,25,28,30,29)	(11,13,15,19,20,14,17)	(24,27,21,25,28,30,29)	(41,49,44,45,48,50,47)
A_4'	(41,49,44,45,48,50,47)	(34,32,33,36,37,38,40)	(24,27,21,25,28,30,29)	(11,13,15,19,20,14,17)

ALGORITHM:

Step 1: The Heptagonal fuzzy number can be defuzzified by using the formula

$$\left(\frac{a+6b+15c+20d+15e+6f+g}{64}\right)$$

After defuzzification we get

	C_1'	C_2'	C_3'	C_4'
A_1'	35.375	25.469	17.109	25.469
A_2'	35.375	17.109	25.469	4.219
A_3'	25.469	17.109	25.469	46.297
A_4'	46.297	35.375	25.469	17.109

Step 2:

Find maximum and minimum values of each column from the defuzzification table by using the Equation (1)

	C_1'	C_2'	C_3'	C_4'
A_1'	35.375	25.469	17.109	25.469
A_2'	35.375	17.109	25.469	4.219
A_3'	25.469	17.109	25.469	46.297
A_4'	46.297	35.375	25.469	17.109
$f_j^*(max)$	46.297	35.375	25.469	46.297
$f_j^-(min)$	25.469	17.109	17.109	4.219

Step 3:

Calculate the S_j and R_j index for each alternatives by using the Equation (2)

S_j	R_j
0.514	0.136
0.631	0.25
0.5	0.25
0.173	0.173

Step 4:

Calculate Q_j by using the Equation (3) and also find the Ranks for the alternative are given by

Alternative	Q_j	Rank
A'_1	0.372	2
A'_2	1	4
A'_3	0.857	3
A'_4	0.165	1

RESULT

The above table clearly shows that A'_4 (Him) has the minimum score value. So, the decision maker has decided to choose the A'_4 (Him) as a best crop .

6. COMPARATIVE ANALYSIS

	Triangular Fuzzy number	Trapezoidal Fuzzy number	Pentagonal Fuzzy number	Hexagonal Fuzzy number	Heptagonal Fuzzy number
A'_1	2	2	2	2	2
A'_2	4	4	4	4	4
A'_3	3	3	3	3	3

A_4'	1	1	1	1	1

7. CONCLUSION:

In this paper, we have compared the different fuzzy numbers using the VIKOR method to find the best crop under all climatic conditions. After analysing the fuzzy numbers, triangular, trapezoidal, pentagonal, hexagonal, and heptagonal, we have the same ranking order, i.e., the decision maker has found the best crop A_4' (HIM) for all climatic changes.

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