Research Article

A new modified Fuzzy S-VIKOR method for best alternative selection

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Abstract: VIKOR is a broadly utilized MCDM method for positioning the attainable other options and choosing the best one. Most of the researchers are used L^1 - norm for calculating utility measure in the VIKOR method. In this research work, a similarity measure is used to modify the VIKOR method. Triangular fuzzy numbers are used in this modified S-VIKOR method to represent the criteria values. The reason of this work was to create modern alteration in VIKOR to avoid complications while solving for enormous numbers of information and non-common criteria. Three different similarity measures are used in this work and also trying to find out the best possible similarity measure for this method. Furthermore, a case study of faculty evaluation for the set of criteria is presented to explain the new method, and comparison is also carried out to show the benefits of this work.

Keywords: Fuzzy VIKOR method, Similarity measure, MCDM method

1. Introduction

MCDM is the way toward finding the best other option. Some significant techniques have been successfully applied to fuzzy decision making problems [1-6]. The VIKOR is a widely used method for multi-criteria analysis. Many researchers work on VIKOR method in the fuzzy system. Alguliyev et. al in 2015 developed hybrid multicriteria decision-making model in the fuzzy environment for personal evaluation [6]. Chatterjee and Chakraborty in 2016 prepared a review of VIKOR method with its variants [7]. Over the last few years, numerous studies have been done with the idea of similarity measures between two intuitive fuzzy sets. Wei and Chen proposed a similarity measure in the fuzzy system for generalized fuzzy numbers [8]. Various similarity methods for the fuzzy numbers are analysed and outlined the advantages by the various researchers[9-10]. Despite a powerful method with a huge range of application in numerous fields, a few researchers worked on similarity measures between two triangular fuzzy numbers and used them in the triangular fuzzy VIKOR method.

Therefore, with the shortcoming of the literature, a similarity measure is used to solve fuzzy VIKOR method in this research work.

2. Methodology

Zadeh (1965) proposed the idea of fuzzy sets and the respective theory that can be considered as the extension of the classical set theory [11]. First, review the basic idea of triangular fuzzy numbers. Next discuss about similarity measure and applied in the fuzzy VIKOR.

2.1 Triangular fuzzy number

Generalized triangular fuzzy number A as $A = (a_1, a_2, a_3)$, where a_1, a_2 and a_3 are real values.

$$\mu_A(x) = \begin{cases} 0, & x \le a_1 \\ \dfrac{x - a_1}{a_2 - a_1}, & a_1 < x \le a_2 \\ \dfrac{a_3 - x}{a_3 - a_2}, & a_2 < x < a_3 \\ 0, & x \ge a_3 \end{cases} \qquad [1]$$

2.2 Similarity measure

Similarity measures between two vectors in vector space were favourably applied to several areas.

Let $A = (a_1, a_2, a_3)$ and $B = (b_1, b_2, b_3)$ be two triangular fuzzy numbers, where $0 \le a_1 \le a_2 \le a_3 \le 1$, $0 \le b_1 \le b_2 \le b_3 \le 1$; the similarity measures for two triangular fuzzy numbers can be defined as follows:

i) Jaccard similarity

$$S_J(A, B) = \frac{\sum_{i=1}^{3} a_i b_i}{\sum_{i=1}^{3} a_i^2 + \sum_{i=1}^{3} b_i^2 - \sum_{i=1}^{3} a_i b_i} \qquad [2]$$

ii) Dice similarity

$$S_E(A,B) = \frac{2\sum_{i=1}^{3} a_i b_i}{\sum_{i=1}^{3} a_i^2 + \sum_{i=1}^{3} b_i^2} \quad [3]$$

iii) Cosine similarity

$$S_C(A,B) = \frac{\sum_{i=1}^{3} a_i b_i}{\sqrt{\sum_{i=1}^{3} a_i^2} \cdot \sqrt{\sum_{i=1}^{3} b_i^2}} \quad [4]$$

2.3 Regret measure

'Regret' is defined as the opportunity of loss by having made the wrong decision. The mini-max regret approach minimizes the maximum regret. This approach is valuable for decision-makers who are insensitive to risk. This method is beneficial for a defendant person who does not wish to make the wrong decision. Here minimum from all maximum regret is selected. Regret is a difference between the best performance and obtained performance value.

2.4 Modified S- VIKOR method

The modified S-VIKOR method is developed for multi-criteria complex systems. VIKOR method useful for ranking and choosing the best alternative. Most of the researcher used aggregation function ($L_p - matric$) to deal with utility measure. In this work, three different similarity measures; Jaccard similarity, Dice similarity and Cosine similarity are used for calculating utility measure.

Step: 1 Define the required criteria, list of alternatives and decision-makers

Let a set of n alternatives are defined by A_i $(i = 1,2, \ldots, n)$ which are to be evaluated based on criteria C_j $(j = 1,2, \ldots, m)$ by k- decision maker, $DM_k (k = 1,2, \ldots p)$.

Step: 2 Define the Linguistic variables and construct performance rating matrix

In this step defining the suitable linguistic variables. x_{ijk} is the fuzzy performance evaluation of alternative A_i concerning to criterion C_j evaluated by k^{th} decision maker DM_k.

Step: 3 Determine the aggregated fuzzy rating

The aggregated fuzzy performance value $\tilde{x}_{ij} = (\tilde{x}_{ij}^l, \tilde{x}_{ij}^m, \tilde{x}_{ij}^u)$ of each alternative can be calculated by using equation (5):

$$\begin{aligned} \tilde{x}_{ij}^l &= \frac{1}{K}\sum_{k=1}^{K} x_{ijk}^l \\ \tilde{x}_{ij}^m &= \frac{1}{K}\sum_{k=1}^{K} x_{ijk}^m \\ \tilde{x}_{ij}^u &= \frac{1}{K}\sum_{k=1}^{K} x_{ijk}^u \end{aligned} \quad [5]$$

Step: 4 Determine the positive ideal and negative ideal solution

In this method, the ideal solution for benefit and cost criterion need to set according to the expectation of the decision-maker, which are determined as,

$$\left.\begin{aligned} \left.\begin{aligned} \tilde{x}_j^* &= \max \text{ of } (\tilde{x}_{ij}) \\ \tilde{x}_j^- &= \min of\ (\tilde{x}_{ij}) \end{aligned}\right\} & \ for\ the\ benefit\ criteria \\ \left.\begin{aligned} \tilde{x}_j^* &= \min \text{ of } (\tilde{x}_{ij}) \\ \tilde{x}_j^- &= \max of\ (\tilde{x}_{ij}) \end{aligned}\right\} & \ for\ the\ cost\ criteria \end{aligned}\right\} \quad [6]$$

Where, $\tilde{x}_j^*$ is the positive ideal solution and $\tilde{x}_j^-$ is the negative ideal solution for j^{th} criteria.

Step: 5 Calculate utility measure and regret measure

In this work, similarity measure is used for calculating utility measure instead of distance formula to handle VIKOR method. Weight of a criterion is defined by w_j $(j = 1,2, \ldots m)$ and calculate by using the worst case method [6]. Let R_j^k be the rank of least important criterion C_j specified by the decision-makerDM_k. The higher is the alternative weight w_j, the higher is its rank R_j, which is expressed as the equation 7

$$\frac{w_1^k}{R_1^k} = \frac{w_2^k}{R_2^k} = \cdots \ldots\ldots = \frac{w_q^k}{R_q^k} = \cdots \ldots = \frac{w_m^k}{R_m^k} \quad [7]$$

Expressions for the weights for each criterion is shown in equation 8,

$$w_1^k = R_1^k \frac{w_q^k}{R_q^k}, \ldots\ldots\ldots\ldots, w_m^k = R_m^k \frac{w_q^k}{R_q^k} \quad [8]$$

Where, w_q^k is represent weight of least important criterion assessed by k^{th} decision maker and R_q^k is represent rank of least important criterion assessed by k^{th} decision maker.

The method demands the following condition to hold:

$$w_1^k + w_2^k + \cdots . + w_q^k + \cdots . + w_m^k = 1 \quad [9]$$

Replacing weights from equation (8) into equation (9), an expression for the weight of the worst criterion is evaluated, which is shown in equation (10).

$$w_q^k = \frac{1}{\frac{R_1^k}{R_q^k} + \frac{R_2^k}{R_q^k} + \cdots \ldots \frac{R_m^k}{R_q^k}} \quad [10]$$

Equations (8) and (10) allow one to calculate the criteria weights.

Thus weighted similarity measures between an alternative A_i and the ideal solution x^* represented by the triangular fuzzy numbers are defined as follows:

$$S^J{}_i(A_i, x^*) = \sum_{j=1}^{m} w_j \cdot \left[\frac{\sum_{k=1}^{3} a_{ijk} \cdot x_{jk}^*}{\sum_{k=1}^{3} a_{ijk}^2 + \sum_{k=1}^{3} x_{jk}^{*2} - \sum_{k=1}^{3} a_{ijk} \cdot x_{jk}^*}\right] \quad [11]$$

$$S^E{}_i(A_i, x^*) = \sum_{j=1}^{m} w_j \cdot \left[\frac{2\sum_{k=1}^{3} a_{ijk} \cdot x_{jk}^*}{\sum_{k=1}^{3} a_{ijk}^2 + \sum_{k=1}^{3} x_{jk}^{*2}}\right] \quad [12]$$

$$S^C{}_i(A_i, x^*) = \sum_{j=1}^{m} w_j \cdot \left[\frac{\sum_{k=1}^{3} a_{ijk} \cdot x_{jk}^*}{\sqrt{\sum_{k=1}^{3} a_{ijk}^2} \cdot \sqrt{\sum_{k=1}^{3} x_{jk}^{*2}}}\right] \quad [13]$$

Regret measure

$$R_i = \max_{j = 1,2, \ldots m} \left|\frac{w_j \cdot (\tilde{x}_j{}^* - \tilde{x}_{ij})}{(\tilde{x}_j{}^* - \tilde{x}_j{}^-)}\right|, \quad i = 1,2 \ldots\ldots n \quad [14]$$

Where, S_i and R_i represent the utility measure and regret measure.

Step: 6 Compute the value of VIKOR index Q_i

The VIKOR index Q_i is calculated by equation (15),

$$Q_i = \lambda \frac{S^* - S_i}{S^* - S^-} + (1 - \lambda) \frac{R^* - R_i}{R^* - R^-}, \quad [15]$$

Where, $\lambda \in [0,1]$ is the weight of the decision making strategy.

Step: 7 Rank the alternatives

The VIKOR index indicate the separation measure of A_i from the best performance. For that sorting the values of Q in ascending order.

Step: 8 Compromise solution

If conditions 1 and 2 are satisfied, then the scheme with a minimum value of Q in ranking is considered the optimal compromise solution according to [6].

Condition - 1 Acceptable advantage

The alternative A^1 has an acceptable advantage, if $\frac{Q(A^2) - Q(A^1)}{Q(A^n) - Q(A^1)} \geq \frac{1}{n-1}$ [6].

Where, A^1 is the best ranked alternative and A^2 is the alternative with second position in the ranking list by the measure Q.

Condition -2 Acceptable stability

The alternative A^1 must also be the best ranked by S or/and R. If one of the conditions is not satisfied, then a set of compromise solutions is proposed [6], which consists of

(i) Alternatives A^1 and A^2 if only condition -2 is not satisfied

(ii) Alternatives $A^1, A^2, \ldots\ldots, A^N$ if condition -1 is not satisfied.

A^N is determined by the relation $Q(A^N) - Q(A^1) < 1/(n-1)$ for maximum N (the positions of these alternatives are "in closeness").

3. Case study

Data for this case study are collected from Navsari Agricultural University's Waghai campus. Seven alternatives, three decision makers and total nineteen criteria are used in this case study.

Step: 1 Define the required criteria, list of alternatives and decision-makers

Seven faculties as an alternatives are denoted by A_i, where $i = 1,2,\ldots,7$; In which three faculties are from College of Agriculture, Waghai, two faculties are from KrishiVigyan Kendra and other two faculties are from Research centre, Waghai. Here, faculties from each category are evaluated by their own set of criteria. Criteria are decide with the help of experts from agriculture college. One criterion is common to all three categories. Criteria are labelled with C_j.

		Criteria No.	Description
Teaching	Subject Knowledge (C^1)	C_1	Knowledge of subject matter
		C_2	Problem solving capability
		C_3	Appropriate teaching methods
	Skills of teaching(C^2)	C_4	Skill of explanation
		C_5	Being available to students for advice and guidance
		C_6	Board work/presentation skill in class room
KVK' s (Extension)	Extension Activity (C^3)	C_7	Popularization of new technology
		C_8	Work in innovation of extension technology and methods in field
		C_9	Involvement in Krishi mela/Exhibition/TV-Radio talk
	Farmer related activity (C^4)	C_{10}	Involvement in training conducted for benefits of farmer
		C_{11}	Problem solving capability of farmers
		C_{12}	Relation/behaviour with farmers
Research centre	Field work (C^5)	C_{13}	Working as PI of research scheme
		C_{14}	Formulation of new research projects in last 3 years
		C_{15}	Farmers recommendations
	Involvement in research (C^6)	C_{16}	Involvement in research committee
		C_{17}	Research projects
		C_{18}	Attend workshop/seminar/ etc.
All	(C^7)	C_{19}	Work ethics

Table - 1 Criteria for faculty evaluation

After deciding criteria committee of three independent decision maker is formed. In which senior scientist from college of agriculture, waghai helped positively for this work. Decision makers are denoted as DM_k; where, $k = 1,2,3$.

Step: 2 Define the Linguistic variables and construct performance rating matrix

To express a value of above criteria, the triangular fuzzy number (TFN) is used. Six different linguistic variables are defined for faculty evaluation.

Linguistic Variable	Grade	Interval
Excellent	E	(8,10,10)
Very Good	VG	(6,8,10)
Good	G	(4,6,8)
Average	A	(2,4,6)
Bad	B	(0,2,4)

Very Bad	VB	(0,0,2)

Table - 2 Linguistic variables for the faculty performance evaluation

Rating of alternatives (faculties) with respect to criteria evaluated by decision makers:

	A_1			A_2			A_3			A_4			A_5			A_6			A_7		
	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3
C_1	VG	VG	E	G	A	G	E	VG	E	-	-	-	-	-	-	-	-	-	-	-	-
C_2	VG	G	VG	G	A	G	G	VG	G	-	-	-	-	-	-	-	-	-	-	-	-
C_3	G	G	VG	G	G	G	VG	G	G	-	-	-	-	-	-	-	-	-	-	-	-
C_4	G	A	G	A	G	A	VG	G	G	-	-	-	-	-	-	-	-	-	-	-	-
C_5	G	A	G	VG	VG	A	VG	G	A	-	-	-	-	-	-	-	-	-	-	-	-
C_6	A	A	G	G	VG	VG	G	A	G	-	-	-	-	-	-	-	-	-	-	-	-
C_7	-	-	-	-	-	-	-	-	-	G	G	A	A	A	G	-	-	-	-	-	-
C_8	-	-	-	-	-	-	-	-	-	A	G	A	G	VG	G	-	-	-	-	-	-
C_9	-	-	-	-	-	-	-	-	-	G	A	G	VG	G	G	-	-	-	-	-	-
C_{10}	-	-	-	-	-	-	-	-	-	VG	G	G	A	VG	A	-	-	-	-	-	-
C_{11}	-	-	-	-	-	-	-	-	-	VG	VG	G	A	VG	G	-	-	-	-	-	-
C_{12}	-	-	-	-	-	-	-	-	-	VG	G	VG	G	G	VG	-	-	-	-	-	-
C_{13}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	VG	A	A	VG	G	G
C_{14}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	A	G	G	A	G
C_{15}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	G	VG	G	A	A
C_{16}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	G	G	A	G	G
C_{17}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	G	A	A	A	VG
C_{18}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	G	A	G	A	G	G
C_{19}	G	VG	VG	E	VG	E	G	G	G	VG	G	VG	G	G	A	A	G	G	G	G	G

Table - 3 Decision matrix

Step: 3 Determine the aggregated fuzzy rating

	Aggregated score						
	A1	A2	A3	A4	A5	A6	A7
C_1	(6.67,8.67,10.00)	(3.33,5.33,7.33)	(7.33,9.33,10.00)	-	-	-	-
C_2	(5.33,7.33,9.33)	(3.33,5.33,7.33)	(4.67,6.67,8.67)	-	-	-	-
C_3	(4.67,6.67,8.67)	(4.00,6.00,8.00)	(4.67,6.67,8.67)	-	-	-	-
C_4	(3.33,5.33,7.33)	(2.67,4.67,6.67)	(4.67,6.67,8.67)	-	-	-	-
C_5	(3.33,5.33,7.33)	(4.67,6.67,8.67)	(4.00,6.00,8.00)	-	-	-	-
C_6	(2.67,4.67,6.67)	(5.33,7.33,9.33)	(3.33,5.33,7.33)	-	-	-	-
C_7	-	-	-	(3.33,5.33,7.33)	(2.67,4.67,6.67)	-	-
C_8	-	-	-	(2.67,4.67,6.67)	(4.67,6.67,8.67)	-	-
C_9	-	-	-	(3.33,5.33,7.33)	(4.67,6.67,8.67)	-	-
C_{10}	-	-	-	(4.67,6.67,8.67)	(3.33,5.33,7.33)	-	-
C_{11}	-	-	-	(5.33,7.33,9.33)	(4.00,6.00,8.00)	-	-
C_{12}	-	-	-	(5.33,7.33,9.33)	(4.67,6.67,8.67)	-	-
C_{13}	-	-	-	-	-	(3.33,5.33,7.33)	(4.67,6.67,8.67)
C_{14}	-	-	-	-	-	(2.67,4.67,6.67)	(3.33,5.33,7.33)
C_{15}	-	-	-	-	-	(4.67,6.67,8.67)	(2.67,4.67,6.67)
C_{16}	-	-	-	-	-	(4.00,6.00,8.00)	(3.33,5.33,7.33)

C_{17}	-	-	-	-	-	(2.67,4.67,6.67)	(3.33,5.33,7.33)
C_{18}	-	-	-	-	-	(3.33,5.33,7.33)	(3.33,5.33,7.33)
C_{19}	(5.33,7.33,9.33)	(7.33,9.33,10.00)	(4.00,6.00,8.00)	(5.33,7.33,9.33)	(3.33,5.33,7.33)	(3.33,5.33,7.33)	(4.00,6.00,8.00)

Table - 4 Aggregated decision matrix

Step: 4 Determine the positive ideal and negative ideal solution

Positive ideal solution X^* is taken to be higher value of defined linguistic variable range, i.e. (8, 10, 10) and negative ideal solution X^- is taken as lower value of defined linguistic variable range, i.e. (0, 0, 2).

Step: 5 Calculate utility measure and regret measure

Calculate weight of the criteria by using worst case method [6]. Least important criterion is ranked with 1. According to that criterion other criteria are ranked by their priority individually. Rank of criteria assigned by each decision maker:

		DM1	**DM2**	**DM3**				**DM1**	**DM2**	**DM3**
C^1	C_1	9	6	8		C^4	C_{10}	5	6	4
	C_2	1	1	1			C_{11}	1	1	1
	C_3	7	5	6			C_{12}	8	7	8
C^2	C_4	3	2	5		C^5	C_{13}	7	1	6
	C_5	1	1	1			C_{14}	1	4	3
	C_6	8	7	6			C_{15}	4	6	1
C^3	C_7	2	1	1		C^6	C_{16}	6	1	1
	C_8	1	3	5			C_{17}	3	2	5
	C_9	5	4	6			C_{18}	1	7	4
						C^7	C_{19}	1	1	1

Table - 5 Rank of each criteria assigned by each decision maker

Weights of criteria are calculated by using equation [9-11], which are shown in table 6

		DM1	**DM2**	**DM3**	**Avg. Weight**				**DM1**	**DM2**	**DM3**	**Avg. Weight**
C^1	w_1	0.53	0.50	0.53	0.52		C^4	w_{10}	0.36	0.43	0.31	0.36
	w_2	0.06	0.08	0.07	0.07			w_{11}	0.07	0.07	0.08	0.07
	w_3	0.41	0.42	0.40	0.41			w_{12}	0.57	0.50	0.62	0.56
C^2	w_4	0.25	0.20	0.42	0.29		C^5	w_{13}	0.58	0.09	0.60	0.42
	w_5	0.08	0.10	0.08	0.09			w_{14}	0.08	0.36	0.30	0.25
	w_6	0.67	0.70	0.50	0.62			w_{15}	0.33	0.55	0.10	0.33
C^3	w_7	0.25	0.13	0.08	0.15		C^6	w_{16}	0.60	0.10	0.10	0.27
	w_8	0.13	0.38	0.42	0.31			w_{17}	0.30	0.20	0.50	0.33
	w_9	0.63	0.50	0.50	0.54			w_{18}	0.10	0.70	0.40	0.40
							C^7	w_{19}	1.00	1.00	1.00	1.00

Table - 8 Weights of the criteria

Utility measure

Here, three different cases are proposed for finding utility measure; Jaccard similarity measure, Dice similarity measure and Cosine similarity measure. Utility measures for these three cases 1, 2 and 3 are calculated by using equation 12, 13 and 14 respectively.

Utility measure			
	Case -1 **Jaccard similarity**	**Case -2** **Dice similarity**	**Case -3** **Cosine similarity**

$S^J{}_1$	2.5740	2.7567	2.9537
$S^J{}_2$	2.6313	2.7912	2.9620
$S^J{}_3$	2.5693	2.7622	2.9566
$S^J{}_4$	2.5772	2.7630	2.9531
$S^J{}_5$	2.5225	2.6853	2.9440
$S^J{}_6$	2.2688	2.5793	2.9302
$S^J{}_7$	2.3598	2.6372	2.9379
S^{J^*}	2.6313	2.7912	2.9620
S^{J^-}	2.2688	2.5793	2.9302

Table – 7 Utility measure

Regret measure:

Regret measure is calculated by using equation (15), table 8 shows the regret measure of all seven alternatives.

	Regret measure
R_1	0.3353
R_2	0.2402
R_3	0.3833
R_4	0.2602
R_5	0.4611
R_6	0.4611
R_7	0.3864
R*	0.2402
R^-	0.4611

Table - 8 Regret measure

Step: 6 Compute the value of VIKOR index Q_i

The VIKOR index Q_i is calculated by using equation (16),

VIKOR index			
	Case -1 **Jaccard similarity**	**Case -2** **Dice similarity**	**Case -3** **Cosine similarity**
Q1	0.4033	0.4037	0.4135
Q2	0.0000	0.0000	0.0000
Q3	0.6001	0.5967	0.5998
Q4	0.0964	0.0948	0.1093
Q5	0.9300	0.9499	0.9566
Q6	1.0000	1.0000	1.0000
Q7	0.6706	0.6683	0.6713

Table - 9 VIKOR index Q_i

Step: 7 Rank the alternatives

Rank the alternative, sorting them by the values Q and R in ascending order and S in descending order.

Case - 1 Jaccard similarity measure

	S	R	$Q_{\lambda=0.1}$	$Q_{\lambda=0.2}$	$Q_{\lambda=0.3}$	$Q_{\lambda=0.4}$	$Q_{\lambda=0.5}$	$Q_{\lambda=0.6}$	$Q_{\lambda=0.7}$	$Q_{\lambda=0.8}$	$Q_{\lambda=0.9}$
A_1	2.5740 [3]	0.3353 [3]	0.4033 [3]	0.3760 [3]	0.3488 [3]	0.3216 [3]	0.2944 [3]	0.2671 [3]	0.2399 [3]	0.2127 [3]	0.1854 [3]
A_2	2.6313 [1]	0.2402 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]
A_3	2.5693 [4]	0.3833 [4]	0.6001 [4]	0.5525 [4]	0.5048 [4]	0.4571 [4]	0.4094 [4]	0.3618 [4]	0.3141 [4]	0.2664 [4]	0.2188 [4]
A_4	2.5772 [2]	0.2602 [2]	0.0964 [2]	0.1023 [2]	0.1082 [2]	0.1141 [2]	0.1200 [2]	0.1259 [2]	0.1318 [2]	0.1376 [2]	0.1435 [2]
A_5	2.5225 [5]	0.4611 [6]	0.9300 [6]	0.8601 [6]	0.7901 [6]	0.7201 [6]	0.6501 [5]	0.5802 [5]	0.5102 [5]	0.4402 [5]	0.3703 [5]
A_6	2.2688 [7]	0.4611 [6]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]
A_7	2.3598 [6]	0.3864 [5]	0.6706 [5]	0.6793 [5]	0.6880 [5]	0.6967 [5]	0.7055 [7]	0.7142 [6]	0.7229 [6]	0.7316 [6]	0.7403 [6]

Table - 10 Ranking of alternatives (Jaccard similarity)

Case - 2 Dice similarity measure

	S	R	$Q_{\lambda=0.1}$	$Q_{\lambda=0.2}$	$Q_{\lambda=0.3}$	$Q_{\lambda=0.4}$	$Q_{\lambda=0.5}$	$Q_{\lambda=0.6}$	$Q_{\lambda=0.7}$	$Q_{\lambda=0.8}$	$Q_{\lambda=0.9}$
A_1	2.7567 [4]	0.3353 [3]	0.4037 [3]	0.3769 [3]	0.3501 [3]	0.3233 [3]	0.2965 [3]	0.2697 [3]	0.2429 [3]	0.2161 [3]	0.1893 [4]
A_2	2.7912 [1]	0.2402 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]
A_3	2.7622 [3]	0.3833 [4]	0.5967 [4]	0.5456 [4]	0.4944 [4]	0.4433 [4]	0.3922 [4]	0.3411 [4]	0.2899 [4]	0.2388 [4]	0.1877 [3]
A_4	2.7630 [2]	0.2602 [2]	0.0948 [2]	0.0990 [2]	0.1032 [2]	0.1075 [2]	0.1117 [2]	0.1160 [2]	0.1202 [2]	0.1244 [2]	0.1287 [2]
A_5	2.6853 [5]	0.4611 [6]	0.9499 [6]	0.8999 [6]	0.8498 [6]	0.7998 [6]	0.7497 [6]	0.6997 [5]	0.6496 [5]	0.5996 [5]	0.5495 [5]
A_6	2.5793 [7]	0.4611 [6]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]
A_7	2.6372 [6]	0.3864 [5]	0.6683 [5]	0.6748 [5]	0.6812 [5]	0.6877 [5]	0.6942 [5]	0.7006 [6]	0.7071 [6]	0.7135 [6]	0.7200 [6]

Table – 11 Ranking of alternatives (Dice similarity)

Case - 3 Cosine similarity measure

	S	R	$Q_{\lambda=0.1}$	$Q_{\lambda=0.2}$	$Q_{\lambda=0.3}$	$Q_{\lambda=0.4}$	$Q_{\lambda=0.5}$	$Q_{\lambda=0.6}$	$Q_{\lambda=0.7}$	$Q_{\lambda=0.8}$	$Q_{\lambda=0.9}$
A_1	2.9537 [3]	0.3353 [3]	0.4135 [3]	0.3965 [3]	0.3795 [3]	0.3626 [3]	0.3456 [3]	0.3286 [3]	0.3116 [3]	0.2946 [4]	0.2776 [4]
A_2	2.9620 [1]	0.2402 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]	0.0000 [1]
A_3	2.9566 [2]	0.3833 [4]	0.5998 [4]	0.5518 [4]	0.5039 [4]	0.4559 [4]	0.4079 [4]	0.3599 [3]	0.3120 [4]	0.2640 [3]	0.2160 [2]
A_4	2.9531 [4]	0.2602 [2]	0.1093 [2]	0.1281 [2]	0.1469 [2]	0.1657 [2]	0.1845 [2]	0.2032 [2]	0.2220 [2]	0.2408 [2]	0.2596 [3]
A_5	2.9440 [6]	0.4611 [6]	0.9566 [6]	0.9132 [6]	0.8698 [6]	0.8264 [6]	0.7830 [6]	0.7395 [6]	0.6961 [5]	0.6527 [5]	0.6093 [5]
A_6	2.9302 [7]	0.4611 [6]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]	1.0000 [7]
A_7	2.9537 [5]	0.3864 [5]	0.6713 [5]	0.6807 [5]	0.6902 [5]	0.6996 [5]	0.7090 [5]	0.7185 [5]	0.7279 [6]	0.7374 [6]	0.7468 [6]

Table - 12 Ranking of alternatives (Cosine similarity)

Step: 8 Compromise solution

Calculate compromise solution for each value λ for all three cases.

For Case 1, when $\lambda = 0.1$

Condition -1 Acceptable advantage

$$\frac{Q(A^2)-Q(A^1)}{Q(A^7)-Q(A^1)} = \frac{0.0964-0.0000}{1.0000-0.0000} = 0.0964 \ngeq \frac{1}{7-1} = 0.1667$$

Here, Condition $C1$ is not satisfied.

Condition -2 Acceptable stability

$A_2$is the best ranked by utility measure (S) and regression measure(R). Hence, condition C2 is satisfied.

Here, Condition (C1) is not satisfied; thus, compromised solution is obtained by using relation $Q(A^N) - Q(A^1) < 1/(n - 1)$ for maximum N.

$A^2 - A^1 = 0.0964 < 0.1667$; $A^3 - A^1 = 0.4033 \nless 0.1667$

Thus alternative $A_2(A^1)$ and A_4 (A^2) are preferred choice, because position of these two alternative are in closeness. Similarly other compromised solution for all the alternatives and for all three cases are also obtained by following above process.

4. Result and Discussion

For each value of λ from 0.1 to 0.9 for each 0.1 interval, compromise solution is calculated for investigate the influence of different λ on the result. Table [10-12] shows the ranking of alternatives, which are calculated in three cases. In all three cases, alternative 2 spotted at the first position and alternative 4 at second position. Also, alternative 6 got the last (7^{th}) position in all three cases.

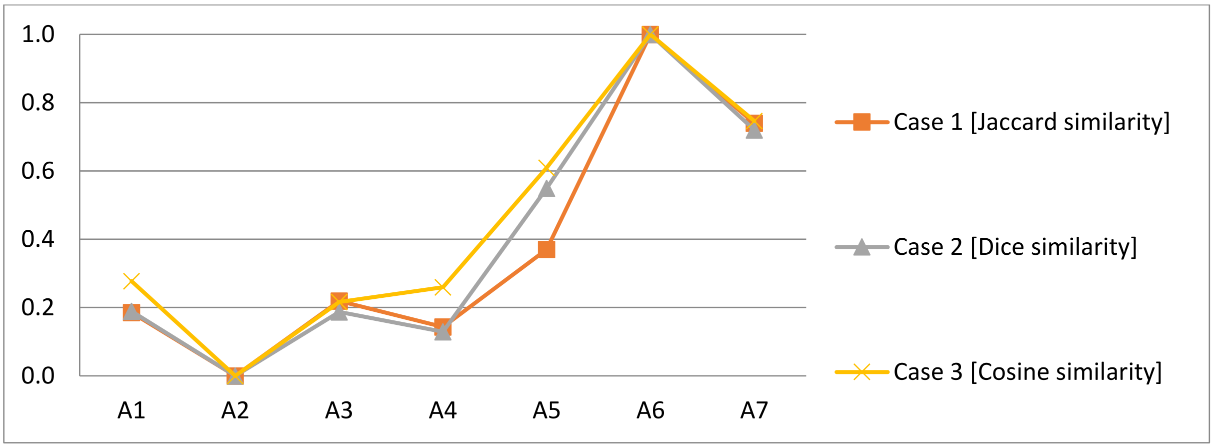

Figure - 1 Performance of Alternative for $\lambda = 0.1$

5. Conclusion

The similarity measure is successful to solve the multi criteria decision making problem, but it hardly ever applies to triangular fuzzy VIKOR method. In this work, three weighted similarity measures have been proposed between two triangular fuzzy numbers and modify VIKOR method with known information on criterion values and weights. Here, the ranking of faculties are assessed in linguistic variable by triangular fuzzy number and the weights of criteria are calculated by using worst case method. In proposed case study similarity measure is used for calculating utility measure. In all three cases we have the same decision results, which show that proposed method is applicable and effective.

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