Comparative Analysis of FDOSM and VIKOR method

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ABSTRACT:

Multi-Criteria Decision Making (MCDM) has recently emerged as the most effective technique for dealing with complicated problems in expert systems. The MCDM is the best technique for providing an appropriate solution. MCDM approaches have faced numerous challenges in academic literature, with uncertainty and vagueness being the most significant challenges. One of the most recent MCDM methods called the fuzzy decision by opinion score method (FDOSM), can address many of these challenges. In this study, we present our methodology in three block units. The first block (data input unit). The second block (data transformation unit). The third block (data-processing unit). Each unit contains steps and mathematical equations. Then, the performance of the FDOSM with the performance of the VIKOR method for the same case study (grinding wheel abrasive material selection problem) has been compared. The result of FDOSM was more logical and consistent with the decision-makers' opinions.

Keywords: Multi-Criteria Decision Making (MCDM), Fuzzy Set, Fuzzy decision by opinion score method (FDOSM), VIKOR

1. INTRODUCTION

MCDM is essentially an approach to reasoning for decision-making that ranks the available preferences in order to choose the most desirable. The purpose of decision-making is to accomplish the most desired objectives with the least amount of anticipated repercussions [1] [2]. Decision-making becomes more complex when there is uncertainty, insufficient knowledge, or several criteria to evaluate. The most widely used decision-making method is

MCDM [٣]. The term MCDM implies decision-making in the context of several objectives or qualities [4]. The MCDM approach is widely used to deal with numerous selection issues and decision-making. The primary goal of MCDM is to assist decision-makers in choosing the best alternatives and rank it based on their effectiveness by selecting the alternatives among available options. For completing the ranking process, many possibilities must be analyzed in order to sort them and select the best one [5] [6]. Any MCDM problem is often displayed as a matrix, as shown below:

$$DM = \begin{matrix} A_1 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}$$

The above m x n two-dimensional matrix has m rows and n columns, with rows A1, A2,... Am representing alternatives and columns C1, C2,... Cn representing criteria. The DM matrix ranked the A1 alternative for each Cj criterion [7] [8] [9]. Essentially, the MCDM techniques have two approaches: mathematical and human. The first approach utilizes mathematical equations such as VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method [10]. Whereas the second method such as the Analytic Hierarchy Process (AHP) method, takes human preferences into account in their computations [11] [12]. Each approach has its own set of challenges [13]: in the mathematical approach's (normalization [14], criteria weight [15], and distance measurement [16] [17] issues. On the other hand, the main problem for the human approach was the inconsistency ratio [18] [19] . Another problem faced by MCDM methodologies (i.e., mathematical and human approaches) was uncertainty and ambiguity. The decision-makers (experts) are unable to identify the weight in real numbers since they use linguistic terms. As a result, the challenges, including this information, become more difficult. Many researchers have tackled this issue [20] [21] [22]. Many studies in the academic literature have advised the use of fuzzy set numbers to address the issue of uncertainty and ambiguity [22] [23] [24] .In 2020, the fuzzy decision by opinion score method (FDOSM) was published as a possible solution for addressing the challenges outlined above [24]. It is an effective and powerful method. The primary idea of FDOSM is to use the optimal solution and an opinion matrix to tackle the challenges listed above. It allows decision-makers to determine and select the best value while also comparing it to other values using the same criteria [25]. FDOSM gives logical decisions based on expert opinions [26]. Many researchers in academic literature have utilized FDOSM to tackle MCDM problems. The authors of [27] proposed a new approach to modeling the applications of smart e-tourism for each e-tourism category. This approach is known as the Spherical Fuzzy Rough Decision by Opinion method (SFR-DOSM). In [28], FDOSM methods were used for the intuitionistic fuzzy set (IFS). The study's approach was separated into two parts. The first part was to generate a decision matrix using the intersection of the DAS alternatives and criterion. The second part (development phase) proposed creating a novel FWZIC II to weigh criteria and a novel FDOSM II to benchmark DASs. [29] uses FDOSM in a homogenous Fermatean fuzzy environment to prioritize the COVID-19 patients who are most likely to benefit from mesenchymal stem cell (MSC) transfusion by giving weights to criteria. A new FDOSM type known as IVP-FDOSM was developed in [30] in order to benchmark and assess SLRSs using an Interval-Valued Pythagorean Fuzzy Set (IVPFS). In this study, we will compare the performance of the FDOSM with the performance of the VIKOR method to reduce the uncertainty and the vague information. Despite the FDOSM and VIKOR methods having the same goals, the rankings produced by these methods both methods are typically different. VIKOR method is VlseKriterijumska Optimizacija I Kompromisno Resenje method, was initially proposed by Opricovic and Tzeng [31]. It is one of the MCDM methods used for ranking and choosing optimum alternatives from a set of alternatives when there are conflicts between various criteria in complex systems [32]. It offers a multi-criterion ranking index depending on the measure of “closeness” to the “ideal” solution. This method is an efficient tool in MCDM, particularly when the decision-maker is unable to express their preferences at the start of the system design [33] [34].

This paper is organized as follows: Section 2 presents the methodology which used in this paper. Section 3 presents the case study. Then, Section 4 shows the results and discussion. Finally, Section 5 presents the conclusion and future work of the study.

2- METHODOLOGY

The FDOSM methodology presented a mathematical model for solving MCDM issues. FDOSM is comprised of three block units: data input, data transformation, and data processing. The FDOSM steps can be expressed in the following form:

Step 1: Construct a decision matrix.

Step 2: Determine the ideal solution for every one of the criteria.

Step 3: To generate the opinion matrix, compare the ideal solution to other values for each criterion based on the decision-maker's opinions.

Step 4: Transform the opinion matrix to triangular fuzzy numbers.

Step 5: Direct aggregation using arithmetic means.

Step 6: The final decisions is the lowest, best.

The following parts describe each unit, with their relevant steps and mathematical equations.

2.1. Data Input Unit

The proposed MCDM method, likewise other MCDM techniques, it has m alternatives (A1,..., Am) and n collections of decision criteria C1,..., Cn. Both of these elements comprise the decision matrix.

$$D = \begin{matrix} A_1 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

This block generates a decision matrix, which is subsequently transformed into an opinion matrix in the next stage [35] [24].

2.2. Data Transformation Unit

Following the establishment of the decision matrix (the output of the first block), FDOSM in this unit chooses an ideal solution with three possible parameters (minimum, maximum, and critical). When calculating cost criteria, the lowest value is used because the lower value indicates a better solution. Benefit criteria are based on the maximum value. The critical value technique is used in select instances, particularly when the ideal answer does not fall between the minimum and maximum values, as in the case of blood pressure. The steps for this stage are given and explained as follows [36] [24].

Step 1: Identify the ideal solution. The ideal solution can be defined as the following:

$$A^* = \left\{\left[\left(\max_i v_{ij} \mid j \in J\right), \left(\min_i v_{ij} \mid j \in J\right), \left(Op_{ij} \in IJ\right) \mid i = 1,2,3, \dots . m\right]\right\}$$

(2)

Where $\max_i v_{ij}$ indicates the ideal value for the benefit criterion, $\min_i v_{ij}$ for the costing criterion, and Op_{ij} represents the critical value when the ideal value falls between $\max_i v_{ij}$ and $\min_i v_{ij}$.

Step 2: Reference Comparison for the ideal solution against other values for each criterion. The technique for assigning weights to evaluation criteria is supplied implaicitly.

The relative importance of the differences between an ideal solution and the alternatives is judged subjectively. Decision-makers are asked to determine whether the relevant discrepancies have significantly influenced their opinion, and the differences are stated by using one of these linguistic terms: Slight difference (Slight-differ), No difference (No-differ), Huge difference (Huge-differ), Difference (Differ), and Big difference (Big-differ).

In Figure 1, the Decision-maker uses equation (2) to nominate V31, V22, V43, and V14 as the optimal solution vectors. After choosing the ideal solution the alternatives are compared to it.

$$Op_{\text{Lang}} = \left\{ \left(\left(\tilde{v}_{ij} \otimes v_{ij} \mid j \in J \right) \cdot \mid i = 1.2.3 \ldots\ldots m \right) \right\}, \qquad (3)$$

Where $\otimes$ means the reference comparison between the ideal solution and the alternatives.

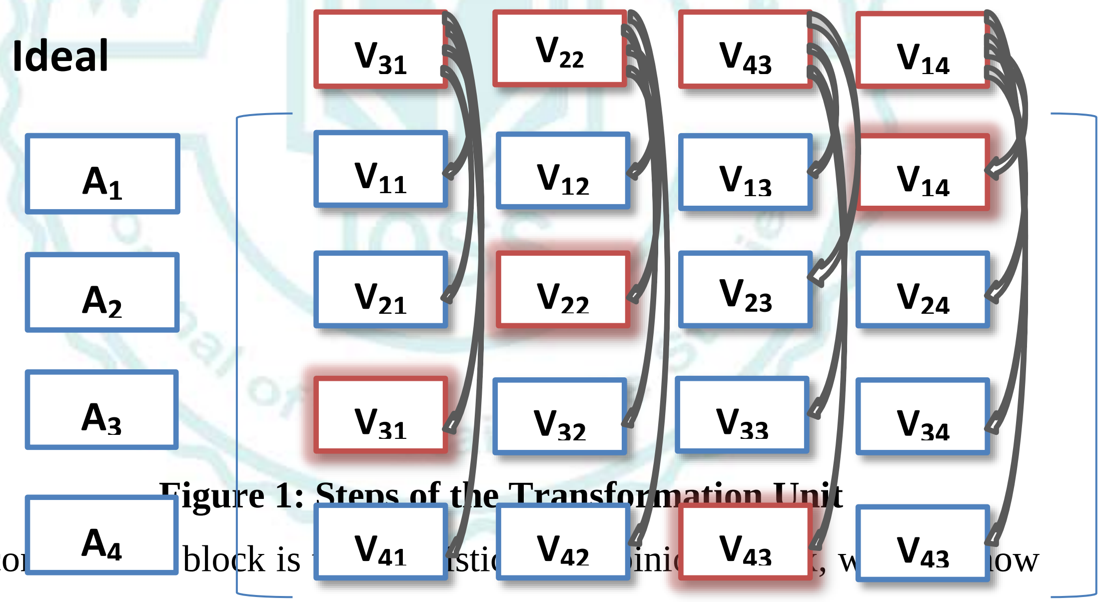

Figure 1: Steps of the Transformation Unit

The outco[illegible] block is [illegible]stic[illegible]inio[illegible], w[illegible] now ready to be converted into a fuzzy number via fuzzy membership.

$$\text{Op\_Lang} = \begin{matrix} A_1 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} op_{11} & \cdots & op_{1n} \\ \vdots & \ddots & \vdots \\ op_{m1} & \cdots & op_{mn} \end{bmatrix}. \qquad (4)$$

2.3. Data Processing Unit

The opinion matrix represents the transformation unit's output. The last block begins by transforming the opinion matrix into a fuzzy opinion decision matrix via TFNs. After that, a direct aggregation operator (such as arithmetic mean) is applied. The steps at this stage are listed and described as the following [25]:

Step 1: To construct a fuzzy decision matrix, the opinion matrix is subjected to a process known as fuzzafication, wherein the opinions terms are substituted with Triangular Fuzzy Numbers (TFNs) is shown in Table 1 to generate a new matrix referred to as the fuzzy opinion decision matrix (FDij).

Table 1: The Value of Linguistic Term With TFN

Linguistic terms	TFNs
No Difference	(0.00, 0.10, 0.30)
Slight Difference	(0.10, 0.30, 0.50)
Difference	(0.30, 0.50, 0.75)
Big Difference	(0.50, 0.75, 0.90)
Huge Difference	(0.75, 0.90, 1.00)

Step 2: Use an aggregation operator, such as the arithmetic mean, to aggregate the results from the previous step for each alternative. After completing the fuzzy decision matrix, the aggregation process is used to determine the optimal alternative, using one of these aggregation operators:

Arithmetic mean $A_{m(x)} = \frac{\sum_{i=1}^{n} x_i}{n}$ (5)

$$A_{m(x)} = \frac{\sum(a_f+a_m+a_l)(b_f+b_m+b_l)(c_f+c_m+c_l)}{n}. \quad (6)$$

Step 3: apply the approach of centroid defuzzification to the aggregation results to obtain a crisp value, which is calculated as follows:

$$\frac{(a+b+c)}{3} \quad (7)$$

3- CASE STUDY

The case study (grinding wheel abrasive material selection problem) with multicriteria decision problems is applied to illustrate the benefit of FDOSM.

In this case study, Maity and Chakraborty (2013)considered a set of eight grinding wheel abrasive materials (A1, A2, A3, A4, A5, A6, A7, A8) and assessed their performance depending on seven criteria: Knoop hardness (in KHN) (C1), modulus of elasticity (in GPa) (C2), compressive strength (in MPa) (C3), shear strength (in MPa) (C4), thermal conductivity (W/mk) (C5), fracture toughness (MPa-m1/2) (C6), and material cost (USD/kg) (C7). All of these criteria, except for grinding wheel abrasive material cost, are beneficial in nature, and higher values are always favored. The decision matrix for this case study is shown in Table 2 [37].

Table 2: The Decision matrix

Alternative	Criteria						
	C1	C2	C3	C4	C5	C6	C7
A1	3200	451	3475	756	17	4.15	18
A2	2400	690	4975	1324	98	3	60
A3	5000	850	6900	1532	13	4.5	864
A4	3000	400	3800	879	30	4	152
A5	8000	953	6700	4688	1200	8.6	1300
A6	2550	440	4600	480	200	3.1	10
A7	2800	460	1721	600	90	2.5	50
A8	1200	160	1750	620	2.2	8.2	45

4- RESULTS AND DISCUSSION

This section offers the results of the FDOSM will be applied to the grinding wheel abrasive material selection problem case study that follows:

4.1. The Result of the Opinion Matrix

This section presents the results obtained from applying the FDOSM to grinding wheel abrasive material selection problem case study and discusses the result. the decision maker determines the ideal solution utilizing equation (2) and then compares it with other values of the same criterion by applying equation (3). The outcome of the comparison was expressed by linguistic terms. As a result of this process, the decision matrix presented in Table 2 is transformed into an opinion matrix for each player position by using a five-point Likert scale, is shown in Table 3.

Table 3: The Opinion Matrix

Alternative	C1	C2	C3	C4	C5	C6	C7
A1	Difference	Big Difference	Big Difference	Huge Difference	Huge Difference	Difference	Slight Difference
A2	Big Difference	Difference	Difference	Big Difference	Big Difference	Big Difference	Difference
A3	Slight Difference	Slight Difference	No Difference	Big Difference	Huge Difference	Difference	Huge Difference
A4	Difference	Big Difference	Big Difference	Huge Difference	Huge Difference	Difference	Big Difference
A5	No Difference	No Difference	Slight Difference	No Difference	No Difference	No Difference	Huge Difference
A6	Big Difference	Big Difference	Difference	Huge Difference	Difference	Big Difference	No Difference
A7	Big Difference	Big Difference	Huge Difference	Huge Difference	Huge Difference	Huge Difference	Difference
A8	Huge Difference	Huge Difference	Huge Difference	Huge Difference	Huge Difference	Slight Difference	Difference

The previous table contains the opinions of the expert as a result of comparing the ideal solution chosen by the expert with the rest of the values for the same criterion.

4.2. Fuzzy Opinion Decision Matrix Result

Opinion matrix is generated using a five-point Likert scale, according to the FDOSM's philosophy. First, we transform the opinion matrix into a fuzzy opinion matrix by converting the linguistic terms into Triangular Fuzzy Numbers as shown in Table 1, resulting in a fuzzy opinion matrix, as demonstrated in Table 4.

Table 4. The Fuzzy Opinion Matrix

Alternative	C1			C2			C3			C4			C5			C6			C7		
A1	0.3	0.5	0.75	0.5	0.75	0.9	0.5	0.75	0.9	0.75	0.9	1	0.75	0.9	1	0.3	0.5	0.75	0.1	0.3	0.5
A2	0.5	0.75	0.9	0.3	0.5	0.75	0.3	0.5	0.75	0.5	0.75	0.9	0.5	0.75	0.9	0.5	0.75	0.9	0.3	0.5	0.75
A3	0.1	0.3	0.5	0.1	0.3	0.5	0	0.1	0.3	0.5	0.75	0.9	0.75	0.9	1	0.3	0.5	0.75	0.75	0.9	1
A4	0.3	0.5	0.75	0.5	0.75	0.9	0.5	0.75	0.9	0.75	0.9	1	0.75	0.9	1	0.3	0.5	0.75	0.5	0.75	0.9
A5	0	0.1	0.3	0	0.1	0.3	0.1	0.3	0.5	0	0.1	0.3	0	0.1	0.3	0	0.1	0.3	0.75	0.9	1
A6	0.5	0.75	0.9	0.5	0.75	0.9	0.3	0.5	0.75	0.75	0.9	1	0.3	0.5	0.75	0.5	0.75	0.9	0	0.1	0.3
A7	0.5	0.75	0.9	0.5	0.75	0.9	0.75	0.9	1	0.75	0.9	1	0.75	0.9	1	0.75	0.9	1	0.3	0.5	0.75
A8	0.75	0.9	1	0.75	0.9	1	0.75	0.9	1	0.75	0.9	1	0.75	0.9	1	0.1	0.3	0.5	0.3	0.5	0.75

In the table above, the linguistic terms for the opinion matrix are transformed to a fuzzy number using Table 1.

In the subsequent step, the result of the previous step was aggregated for each alternative through the use of an aggregation equation (6) as illustrated in Table 5.

Table 5: Aggregation Step

Alternative	Score		
A1	3.2	4.6	5.8
A2	2.9	4.5	5.85
A3	2.5	3.75	4.95
A4	3.6	5.05	6.2
A5	0.85	1.7	3
A6	2.85	4.25	5.5
A7	4.3	5.6	6.55
A8	4.15	5.3	6.25

Following this, the final results of the decision-maker is obtained by applying the defuzzification equation (7) to the preceding matrix, as illustrated in Tables 6.

Table 6: The Final Result

Alternative	Defuzzy	
	Score	**Rank**
A1	4.533333333	5
A2	4.416666667	4
A3	3.733333333	2
A4	4.95	6
A5	1.85	1
A6	4.2	3
A7	5.483333333	8
A8	5.233333333	7

In the table above, Based on FDOSM philosophy, the best alternative is near to the linguistic term "No difference" (the ideal solution). In Table 6, the best alternative is A5, which has a value closest to the no-difference linguistic term (the ideal solution). otherwise, A7 is the worst alternative because it is far value from the ideal solution.

4.3. comparative Analysis with VIKOR method

Finally, compare and analyzes the differences between the final scores generated by utilizing the FDOSM and the VIKOR method for the same case study is shown in Table 7.

Table 7: Comparison between FDOSM and VIKOR method

Alternative	FDOSM		VIKOR	
	Score	Rank	Score	Rank
A1	4.533333333	5	0.6860	6
A2	4.416666667	4	0.6319	3
A3	3.733333333	2	0.3021	2
A4	4.95	6	0.6434	4
A5	1.85	1	0	1
A6	4.2	3	0.6542	5
A7	5.483333333	8	0.9498	7
A8	5.233333333	7	0.9971	8

In the table above, the best alternative to the FDOSM method and VIKOR method were the same alternative for both methods was (A5).

However, we clearly observe some variances in the final ranking for several alternatives (A1, A2, A4, A6, A7 and A8) as the rank of the alternative (A1) in VIKOR was "6 " and became "5" in the FDOSM, and the alternative (A2) was "3" and became"4", and the alternative (A4) was "4 " and became "6". As for the alternative (A6), it was "5" and became "3". While the alternative (A7) was "7" and became "8", and the alternative (A8) was "8" and became "7".

Finally, it can be concluded that the final rank of FDOSM is logical and in line with the opinion of expert's. Furthermore, the FDOSM method addressed the uncertainty problem better than other MCDM methods and was more effective for addressing the issue of ambiguity in expert opinions.

5- CONCLUSION

To deal with complicated real-world problems, MCDM approaches are widely used in operations research and expert systems. In academic literature, MCDM approaches face numerous challenges. One of the most significant issues is uncertainty and ambiguity. Several scholars suggested using the fuzzy environment to overcome these problems. There are numerous types and extensions of fuzzy environments, and researchers continue developing new extensions. The FDOSM is the most recent MCDM method in a fuzzy environment. The methodology of this study is composed of three block units: the units for data input, data transformation, and data processing. In this paper, we compare the performance of the FDOSM with the performance of the VIKOR method for the same case study (grinding wheel abrasive material selection problem). The decision matrix of the grinding wheel abrasive material selection problem contained 8 alternatives from which decision-makers had to select based on 7 criteria. In analyzing the differences between the final scores generated by utilizing the FDOSM and the VIKOR method, we found that the results of FDOSM are more logical and consistent with decision-makers opinions. As a future work, we recommend using the

(FDOSM) with other MCDM methods to enhance addressing the uncertainty and vagueness in the decision-making process to a significant degree.

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