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A Comprehensive study on the Women Disparities in the society using the Methodology of Multi-Criteria Decision Making

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Abstract:

MCDMs are the unique tool for making decisions and variety of MCDM methods are used halfway around the world aiding in choosing the best option among the multiple alternatives based on various criteria. In this work we have applied the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method that represents a solution methodology for Fuzzy TOPSIS with Heptagonal Fuzzy numbers and each alternative's rating is indicated by Heptagonal Fuzzy Numbers. So, when compared to TOPSIS using triangular numbers we obtain improved and more accurate results. For application and verification, a numerical instance is provided that deals with the Disparities of Women faced in the community.

Keywords: MCDM method – Positive Ideal Solution (PIS) - Negative Ideal Solution (NIS) -TOPSIS – Heptagonal Fuzzy Numbers (HFN) – Distance of two heptagonal fuzzy numbers – Disparities of Women.

1. Introduction

People make decisions on a regular basis, whether they realize it or not. It's similar to speaking prose. Therefore, having a thorough grasp of the decision-making processes could aid in both preventing and encouraging the incorrect decisions. To handle such complexity, a large number of models, theories, and decision support systems are produced [8]. TOPSIS, which “Hwang and Yoon” created [7]. It is used to express the rankings of the alternatives based on the criteria [12]. Here, we have implemented a TOPSIS decision- making method by utilizing heptagonal fuzzy numbers to integrate expert statements. We use this fuzzy number to more closely evaluate the information provided by the experts, and we find that the opinions are 7-tuple fuzzy values. TOPSIS decision-making approach using hexagonal, pentagonal, trapezoidal, and triangular fuzzy numbers to be a little ambiguous due to its enhanced dimensionality [6]. A fuzzy method for assessing consumers (buyers) was presented by Lin and Chang [10].

The fuzzy TOPSIS was then applied to the assessment findings to screen orders. An integrated approach of fuzzy TOPSIS and fuzzy AHP was presented by Kamble and Naziya [9] and used to address the staff selection problem. The TOPSIS approach has been effectively utilized in a variety of domains, and numerous articles on its implementation have been completed so we have suggested TOPSIS decision-making method that integrates the opinions using heptagonal fuzzy numbers in order to address this inadequacy. Thus, we could make decision in a precise manner using this method. The framework of the study is followed. In section 2, the Fuzzy set, Heptagonal fuzzy number, Operations and Distance formula of the Heptagonal numbers are introduced and we have proposed the procedure for TOPSIS method. In section 3, the method and algorithm are given. In section 4 the numerical illustration is given related with disparities faced by women in the society is given. The paper is concluded by ranking the alternatives by their performance score. Acknowledgement and References are followed.

2. Methodology

2.1 Preliminaries

2.1 Heptagonal Fuzzy Number [HFN]

A fuzzy number $\widetilde{N} = (q, r, s, t, u, v, w)$ is a customary Heptagonal fuzzy number where q, r, s, t, u, v, w are real numbers and $q \le r \le s \le t \le u \le v \le w$ with membership function is given below,

$$\mu_{\widetilde{N}}(x) = \begin{cases} \frac{1}{2}\frac{(x-q)}{(r-s)}, q \le x \le r \\ \frac{1}{2}, for\ r \le x \le s \\ \frac{1}{2} + \frac{1}{2}\frac{(x-s)}{(t-s)}, for\ s \le x \le t \\ \frac{1}{2} + \frac{1}{2}\frac{(u-x)}{(v-u)}, for\ t \le x \le u \\ \frac{1}{2}, for\ u \le x \le v \\ \frac{1}{2}\frac{(w-x)}{(w-v)}, for\ v \le x \le w \\ 0, otherwise \end{cases}$$

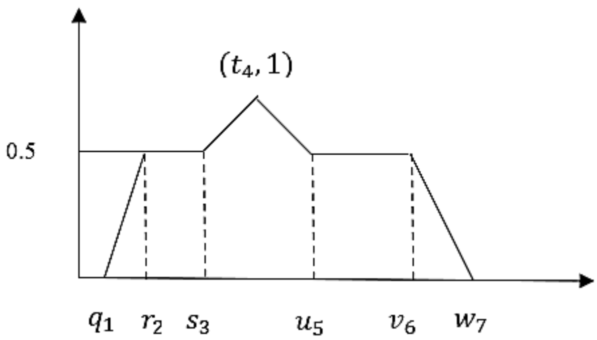

Figure 1: Graphical representation of HFN

2.2 Arithmetic Operations on Heptagonal Fuzzy Numbers

Consider two positive HFN $\widetilde{N} = (q_1, r_1, s_1, t_1, u_1, v_1, w_1)$ and $\widetilde{M} = (q_2, r_2, s_2, t_2, u_2, v_2, w_2)$ then operations on these two positive HFNs are given below,

1. Addition: $\widetilde{N} \oplus \widetilde{M} = (q_1 + q_2, r_1 + r_2, s_1 + s_2, t_1 + t_2, u_1 + u_2, v_1 + v_2, w_1 + w_2)$
2. Subtraction: $\widetilde{N} - \widetilde{M} = (q_1 - w_2, r_1 - v_2, s_1 - u_2, t_1 - t_2, u_1 - s_2, v_1 - r_2, w_1 - q_2)$
3. Multiplication: $\widetilde{N} * \widetilde{M} = (q_1 * w_2, r_1 * v_2, s_1 * u_2, t_1 * t_2, u_1 * s_2, v_1 * r_2, w_1 * q_2)$

4. Division: $\tilde{N}/\tilde{M} = q_1/w_2, r_1/v_2, s_1/u_2, t_1/t_2, u_1/s_2, v_1/r_2, w_1/q_2$

2.3 The distance between two Heptagonal fuzzy numbers

Let $\tilde{N} = (q_1, r_1, s_1, t_1, u_1, v_1, w_1)$ and $\tilde{M} = (q_2, r_2, s_2, t_2, u_2, v_2, w_2)$ are two HFNs, then the hamming distance of $\tilde{N}$ from $\widetilde{M}$ is given by,

$$d(\tilde{N}, \widetilde{M}) = \frac{1}{7}(|q_1 - q_2| + |r_1 - r_2| + |s_1 - s_2| + |t_1 - t_2| + |u_1 - u_2| + |v_1 - v_2| + |w_1 - w_2|)$$

3. Methods and Algorithm

- Describe the linguistic variable. HFN are used to express the variables.
- Create a fuzzy decision matrix using the HFNs. Every entry in the decision matrix contains the HFN and it is given by,

$$DM = \begin{pmatrix} \zeta_{11} & \zeta_{12} & \cdot & \cdot & \cdot & \zeta_{1m} \\ \zeta_{21} & \zeta_{22} & \cdot & \cdot & \cdot & \zeta_{2m} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \zeta_{n1} & \zeta_{n2} & \cdot & \cdot & \cdot & \zeta_{nm} \end{pmatrix} \quad (1)$$

Where, $\zeta_{ij} = (\zeta_{ij1}, \zeta_{ij2}, \zeta_{ij3}, \zeta_{ij4}, \zeta_{ij5}, \zeta_{ij6}, \zeta_{ij7}), i = 1,2,3, \dots, m ; j = 1,2,3, \dots, n$ denotes the number of criteria and alternatives.

- Form a normalized decision matrix denoted by φ_{ij} and is calculated as,

$$\varphi_{ij} = \frac{\zeta_{ij}}{\sqrt{\sum_{j=1}^{n} (\widetilde{\zeta_{ij}})^2}}, i = 1,2,3, \dots, m \quad (2)$$

- Formulate a weighted normalized decision matrix denoted by the value

$$\tilde{v}_{ij} = \tilde{\varphi}_{ij} \times \tilde{\omega}_{ij} \quad i = 1,2,3, \dots, m ; j = 1,2,3, \dots, n \quad (3)$$

$\tilde{\omega}_{ij}$ is the weightage of the criteria.

- Applying Equations (4) and (5), determine the PIS and NIS, respectively.

$$\xi_J^+ = \{\tilde{\alpha}_1^+, \tilde{\alpha}_2^+, \tilde{\alpha}_3^+, \tilde{\alpha}_4^+\} \quad (4)$$

$$\xi_J^- = \{\tilde{\alpha}_1^-, \tilde{\alpha}_2^-, \tilde{\alpha}_3^-, \tilde{\alpha}_4^-\} \quad (5)$$

- Establish the measures for separation from PIS and NIS using the equations (6) and (7) respectively.

$$\eta_i^{+} = \sqrt{\sum_{j=1}^{n} d(\tilde{\alpha}_j^{+}, \tilde{v}_{ij})^2}, i = 1,2,3, \dots, m. \quad (6)$$

$$\eta_i^{-} = \sqrt{\sum_{j=1}^{n} d(\tilde{\alpha}_j^{-}, \tilde{v}_{ij})^2}, i = 1,2,3, \dots, m. \quad (7)$$

Where, $d\left(\tilde{\alpha}_j^{+}, \tilde{v}_{ij}\right)$ and $d(\tilde{\alpha}_j^{-}, \tilde{v}_{ij})$ are determined by the distance formula of Heptagonal fuzzy number.

- Determine how far each option is from the ideals of the positive and negative solutions which are defined as the relative proximity.

$$cl_i^{+} = {(\eta_i^{+})}\Big/{(\eta_i^{+} + \eta_i^{-})} \quad (8)$$

$$cl_i^{-} = {(\eta_i^{-})}\Big/{(\eta_i^{+} + \eta_i^{-})} \quad (9)$$

- Ranking the alternatives: For cl_i^{+} all of the options are shown in order of decreasing proximity to the highest. Additionally, the ranking order of all possibilities for cl_i^{-} is provided, ranging from the closest to the furthest.

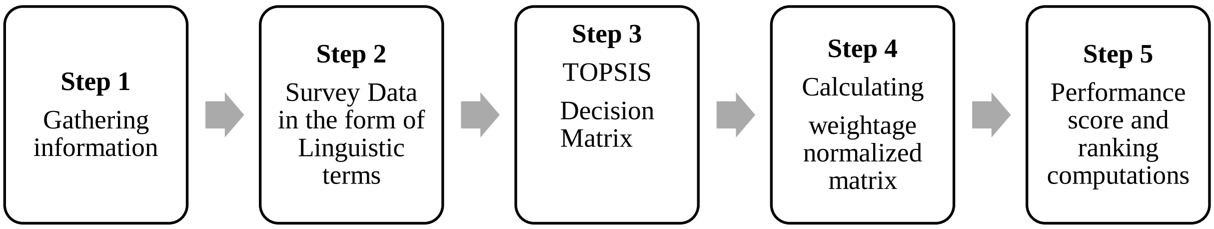

Figure 2: Proposed Framework Flowchart

2. Numerical Illustration

The following characteristics are gathered for 50 women using a self-separate approach. The TOPSIS method is suggested as a tool. The criteria $\mathcal{S}_1, \mathcal{S}_2, \mathcal{S}_3, \mathcal{S}_4$ are related to the disparities that women confront, and the options $\mathcal{Q}_1, \mathcal{Q}_2, \mathcal{Q}_3, \mathcal{Q}_4, \mathcal{Q}_5, \mathcal{Q}_6, \mathcal{Q}_7$ are related to the effects of disparities. Characteristics associated with the inequalities that women experience are used as standards.

$\mathcal{S}_1 - Education$

$\mathcal{S}_2 - Health\ and\ Well\ being$

$\mathcal{S}_3 - Economic\ participation$

$\mathcal{S}_4 - Political\ Participation$

Attributes associated with the absence of inequalities in society are considered alternatives.

$\mathcal{Q}_1 - Work - life\ balance$

$\mathcal{Q}_2 - Safety\ concerns$

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$Q_3 - Violence\ against\ women$

$Q_4 - Gender\ Stereotypes$

$Q_5 - Financial\ Implications$

$Q_6 - Poverty$

$Q_7 - Health\ issues$

The decision-maker assigns the weights based on a subjective method for the criteria

W = (0.4,0.3,0.2,0.1).

1. The decision-maker uses the linguistic terms listed in Tables 1 and 2 to compare criteria or alternatives.
2. Create a decision matrix using the data gathered. The HFN, which is displayed in Table 3, provides the entries of a decision matrix.
3. Creating the normalized matrix with Eq. (2), as indicated in Table 4.
4. Constructing a weighted matrix with Eq. (3), the other values are calculated which is shown in Table 4.
5. Using Eqns. (4) and (5) compute the PIS and NIS.

$$\xi_J^+ = \{\tilde{\alpha}_1^+, \tilde{\alpha}_2^+, \tilde{\alpha}_3^+, \tilde{\alpha}_4^+\}$$

$$\xi_J^- = \{\tilde{\alpha}_1^-, \tilde{\alpha}_2^-, \tilde{\alpha}_3^-, \tilde{\alpha}_4^-\}$$

6. Equations (6) and (7) are used to compute each alternative's distance.

Table 1 Linguistic terms and their corresponding HFN

S.No.	**Linguistic Variables**	**Heptagonal fuzzy numbers**
1	Very high (VH)	(7,9,11,13,15,17,19)
2	High (H)	(6,8,10,12,14,16,18)
3	Medium High (MH)	(5,7,9,11,13,15,17)
4	Neutral (N)	(4,6,8,10,12,14,16)
5	Medium low (ML)	(3,5,7,9,11,13,15)
6	Low (L)	(2,4,6,8,10,12,14)
7	Very Low (VL)	(1,3,5,7,9,11,13)

Table 2 Rating of alternatives by decision maker

	$\mathcal{S}_1$	$\mathcal{S}_2$	$\mathcal{S}_3$	$\mathcal{S}_4$
Q_1	MH	H	N	ML
Q_2	MH	L	H	N
Q_3	L	N	ML	VL
Q_4	H	N	VH	H
Q_5	MH	L	N	ML

Q_6	VL	MH	MH	ML
Q_7	L	ML	N	VL

Table 3 The decision matrix using HFN

	S_1	S_2	S_3	S_4
Q_1	(5,7,9,11, 13,15,17)	(6,8,10, 12,14,16,18)	(4,6,8,1 0,12,14,16)	(3,5,7, 9,11,13,15)
Q_2	(5,7,9,11, 13,15,17)	(2,4,6, 8,10,12,14)	(6,8,10, 12,14,16,18)	(4,6,8, 10,12,14,16)
Q_3	(2,4,6, 8,10,12,14)	(4,6,8, 10,12,14,16)	(3,5,7, 9,11,13,15)	(1,3,5, 7,9,11,13)
Q_4	(6,8,10, 12,14,16,18)	(4,6,8, 10,12,14,16)	(7,9,11, 13,15,17,19)	(6,8,10, 12,14,16,18)
Q_5	(5,7,9, 11,13,15,17)	(2,4,6, 8,10,12,14)	(4,6,8, 10,12,14,16)	(3,5,7, 9,11,13,15)
Q_6	(1,3,5, 7,9,11,13)	(5,7,9, 11,13,15,17)	(5,7,9, 11,13,15,17)	(3,5,7, 9,11,13,15)
Q_7	(2,4,6, 8,10,12,14)	(3,5,7, 9,11,13,15)	(4,6,8, 10,12,14,16)	(1,3,5, 7,9,11,13)

Table 4 Normalized Matrix

	S_1	S_2	S_3	S_4
Q_1	(0.19,0.27,0.35,0.4 2, 0.50, 0.58,0.65)	(0.23,0.30,0.39,0.4 6, 0.54, 0.62,0.69)	(0.14,0.21,0.28,0.3 5, 0.42, 0.49,0.56)	(0.14,0.21,0.28,0.3 5, 0.42, 0.49,0.56)
Q_2	(0.19,0.27,0.35,0.4 2, 0.50, 0.58,0.65)	(0.08,0.15,0.23,0.3 1, 0.39, 0.46,0.54)	(0.21,0.28,0.35,0.4 2, 0.49, 0.56,0.63)	(0.21,0.28,0.35,0.4 2, 0.49, 0.56,0.63)
Q_3	(0.07,0.15,0.23,0.3 0, 0.39, 0.46,0.53)	(0.15,0.23,0.31,0.3 9, 0.46, 0.54,0.62)	(0.11,0.16,0.25,0.3 2, 0.39, 0.46,0.53)	(0.11,0.16,0.25,0.3 2, 0.39, 0.46,0.53)
Q_4	(0.23,0.30,0.39,0.4 6, 0.53, 0.61,0.69)	(0.15,0.23,0.31,0.3 9, 0.46, 0.54,0.62)	(0.24,0.32,0.39,0.4 6, 0.53, 0.60,0.67)	(0.24,0.32,0.39,0.4 6, 0.53, 0.60,0.67)
Q_5	(0.19,0.27,0.35,0.4 2, 0.50, 0.58,0.65)	(0.08,0.15,0.23,0.3 1, 0.39, 0.46,0.54)	(0.14,0.21,0.28,0.3 5, 0.42, 0.49,0.56)	(0.14,0.21,0.28,0.3 5, 0.42, 0.49,0.56)
Q_6	(0.03,0.11,0.19,0.2 7, 0.35, 0.42,0.50)	(0.19,0.27,0.35,0.4 2, 0.50, 0.58,0.66)	(0.18,0.25,0.31,0.3 9, 0.46, 0.53,0.60)	(0.18,0.25,0.31,0.3 9, 0.46, 0.53,0.60)
Q_7	(0.07,0.15,0.23,0.3 0, 0.39, 0.46,0.53)	(0.12,0.19,0.27,0.3 5, 0.42, 0.50,0.58)	(0.14,0.21,0.28,0.3 5, 0.42, 0.49,0.56)	(0.14,0.21,0.28,0.3 5, 0.42, 0.49,0.56)

Table 5 Weighted Normalized Matrix

	$\mathcal{S}_1$	$\mathcal{S}_2$	$\mathcal{S}_3$	$\mathcal{S}_4$
$\mathcal{Q}_1$	(0.08,0.11,0.14,0.17, 0.2, 0.23,0.26)	(0.06,0.09,0.12, 0.14, 0.16,0.19,0.21)	(0.03,0.04,0.05,0.07,0.08,0.09,0.11)	(0.01,0.02,0.03, 0.04, 0.05,0.06,0.07)
$\mathcal{Q}_2$	(0.08,0.11,0.14,0.17, 0.2, 0.23,0.26)	(0.02,0.05,0.07, 0.09, 0.12,0.14,0.16)	(0.04,0.05,0.07,0.08,0.09,0.11,0.13)	(0.01,0.02,0.03, 0.04, 0.05,0.06,0.07)
$\mathcal{Q}_3$	(0.03,0.06,0.10, 0.12, 0.16,0.18,0.21)	(0.05,0.07,0.09, 0.12, 0.14,0.16,0.19)	(0.02,0.03,0.05,0.06,0.08,0.09,0.11)	0.00,0.01,0.02,0.03, 0.04, 0.05,0.06)
$\mathcal{Q}_4$	(0.09,0.12,0.16, 0.18, 0.21,0.24,0.28)	(0.05,0.07,0.09, 0.12, 0.14,0.16,0.19)	(0.05,0.06,0.08,0.09,0.11,0.12,0.13)	(0.02,0.03,0.04, 0.05, 0.06,0.07.0.08)
$\mathcal{Q}_5$	(0.08,0.11,0.14,0.17, 0.2, 0.23,0.26)	(0.02,0.05,0.07, 0.09, 0.12,0.14,0.16)	(0.03,0.04,0.05,0.07,0.08,0.09,0.11)	(0.01,0.02,0.03, 0.04, 0.05,0.06,0.07)
$\mathcal{Q}_6$	(0.01,0.04,0.08, 0.11, 0.14,0.17,0.2)	(0.06,0.08,0.11,0.13, 0.15,0.17,0.20)	(0.04,0.05,0.06,0.08,0.09,0.11,0.12)	(0.01,0.02,0.03, 0.04, 0.05,0.06,0.07)
$\mathcal{Q}_7$	(0.03,0.06,0.10, 0.12, 0.16,0.18,0.21)	(0.04,0.06,0.08, 0.11, 0.13,0.15,0.17)	(0.03,0.04,0.05,0.07,0.08,0.09,0.11)	(0.00,0.01,0.02, 0.03, 0.04,0.05,0.06)

$\tilde{\alpha}_j^+ = (0.1829, 0.1386, 0.0814, 0.05)$

$\tilde{\alpha}_1^+$ =(0.09,0.12,0.16,0.18,0.21,0.24,0.28)

$\tilde{\alpha}_2^+$ =(0.06,0.09,0.12,0.14,0.16,0.19,0.21)

$\tilde{\alpha}_3^+$ =(0.04,0.05,0.07,0.08,0.09,0.11,0.13)

$\tilde{\alpha}_4^+$ =(0.02,0.03,0.04,0.05,0.06,0.07.0.08)

$\tilde{\alpha}_j^-$ = (0.1229,0.0929,0.0629,0.03)

$\tilde{\alpha}_1^-$ =(0.03,0.06,0.10,0.12,0.16,0.18,0.21)

$\tilde{\alpha}_2^-$ =(0.02,0.05,0.07,0.09,0.12,0.14,0.16)

$\tilde{\alpha}_3^-$ =(0.02,0.03,0.05,0.06,0.08,0.09,0.11)

$\tilde{\alpha}_4^-$ =(0.00,0.01,0.02,0.03,0.04,0.05,0.06)

Table 6 Performance rating for every option using the suggested approach

S.No	Alternatives	Performance score	Ranking
1	Q_1	0.83556	2
2	Q_2	0.85691	4
3	Q_3	0.86516	5
4	Q_4	0.74944	1
5	Q_5	0.83907	3
6	Q_6	0.8758	6
7	Q_7	0.90344	7

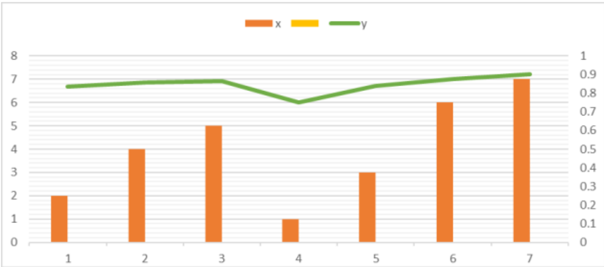

Figure 3: Graphical analysis for Performance Score

3. Discussion

We infer that the accuracy rises with increasing the fuzzy number. Heptagonal fuzzy numbers with subjective opinions incorporated into them actually reduce ambiguity and the resulting results provide a better option than the other way. In this proposed method alternative "$\boldsymbol{Q_4}$", which states that gender stereotypes are more prevalent in society and that women must deal with them comes in first. $\boldsymbol{Q_1}$, $\boldsymbol{Q_5}, \boldsymbol{Q_2}, \boldsymbol{Q_3}, \boldsymbol{Q_6}$ that ranks the second, third, fourth, fifth, sixth respectively and $\boldsymbol{Q_7}$ ranks the last. While in comparing the other fuzzy numbers [17] we get the better results.

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