The Fuzzy TOPSIS Approach to Assessing Obesity Risk in a Comprehensive Range of Disease Factors

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Article Info
Page Number: 3515-3524
Publication Issue:
Vol. 71 No. 4 (2022)

Article History
Article Received: 25 March 2022
Revised: 30 April 2022
Accepted: 15 June 2022
Publication: 19 August 2022

Abstract
TOPSIS ("Technique for Order of Preference by Similarity to Ideal Solution") is a ranking system which is used to rank the criteria in decision making problems. In many real-world situations, decision data of human judgments is often ambiguous and making traditional techniques of using crisp numbers becomes unsuitable. When the uncertainties occur at eight different points, triangular and trapezoidal numbers are not viable. As a result, the TOPSIS approach is extended to study the obesity risk factors using octagonal fuzzy numbers. Further, their arithmetic operations, as well as linguistic values are derived.
Keywords: Linguistic variable (LV), Fuzzy Number (FN), Fuzzy sets (FS) and TOPSIS Algorithm, Octagonal Fuzzy Number (OFN).

1. Introduction:

Zadeh proposed fuzzy theory in 1965 as an expansion of the classical set [1], To make a better decision with the ambiguity, uncertainty of human thoughts and words, fuzzy set has been used in various multiple attribute decision making (MADM) to control vagueness. Hwang & Yoon presented the TOPSIS method, which is a simple ranking method for solving MADM [2]. When faced with a decision-making problem, experts may use ambiguous natural words to represent the facts. In decision analysis, the ambiguous linguistic word is frequently used as input. Some fuzzy TOPSIS algorithms have been developed in the last decade for solving problems in various fields, such as order selection when orders exceed production capacity [3].

When the pancreas fails to secrete enough insulin to meet the body's needs, metabolic problems develop [3]. Insulin's responsibility is to maintain blood sugar levels in the human body [4]. Using the Mamdani approach for DM disease detection with age, weight, and blood pressure as input variables [5], The adaptive neural FIS application was used to predict and classify DM [6], Using the Sugeno method to determine the type of diabetes given age, insulin levels, and body weight as input variables [7],In a hazy and uncertain environment, soft settings are said to be more exact. Many researchers have discussed the applications, focusing on MCDM problems, but an expanded TOPSIS has recently been proposed, which uses an accuracy function in an uncertain and ambiguous environment [8]. However, due to their graphical representations, fuzzy numbers can still address some problems. The use of octagonal numbers to rank optimal solutions is also proposed in [9-10]. In problems with fluctuations, fuzzy numbers are used. In an uncertain environment, triangular, trapezoidal, and pentagonal numbers are used to deal with fluctuations [11-13]. Researchers are now concentrating their research on the development of new concepts to solve MCDM problems. Many studies and research has been conducted in the topic of fuzzy numbers; however there is still a void in the field of octagonal numbers [13-15].

This present study is to Assessing Obesity Risk in a Comprehensive Range of Disease Factors, the diabetes Mellitus (DM) is derived from two Latin words: diabetes, which means "to drain," and Mellitus, which means "sweet." This is caused by metabolic changes which cause blood sugar levels to rise (hyperglycemia).

2. PRELIMINARIES

Definition: A FS$\check{T} \subseteq \H{U}$, it is distinguished by a membership function $\mu_{\check{T}}(z)$ representing a mapping$\mu_{\check{T}}(z): \H{U} \to [0,1]$. The membership value of $\mu_{\check{T}}(z)$ is a function that indicates the degree of truth that z is an element of fuzzy set$\check{T}$.

Definition: A FS$\check{T}$ defined on$\breve{G}$ where $\breve{G}$be the set of real numbers, is said to be a FN and its membership function $\check{T}: \breve{G} \to [0,1]$ has satisfied the characteristics below is

(i) convex $\mu_{\check{T}}(z)(\acute{\alpha} z_1 + (1-\acute{\alpha}) z_2) \geq \min(\mu_{\check{T}}(z_1), \mu_{\check{T}}(z_2), \forall z[z_1, z_2], \acute{\alpha} \in [0,1]$
(ii) Normal,$Max\ \mu_{\check{T}}(z) = 1$.
(iii) Piecewise continuous.

Definition: The α-cut of the FS$\check{T} \subseteq \H{U}$is described as$\check{T}_\sigma = \{z \in \H{U} / \mu_{\check{T}}(z) \geq \sigma\}$, where. $\sigma \in [0,1]$.

Definition 2.3. A Octagonal FN$\tilde{O}$is described as$(a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8)$, and the membership function is described $\mu_{\tilde{O}}(x)$,

$$\mu_{\tilde{O}}(x) = \begin{cases} 0\ , & x < a_1 \\ \frac{1}{4}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \leq x \leq a_2 \\ \frac{1}{4}+\frac{1}{4}\left(\frac{x-a_2}{a_3-a_2}\right), & a_2 \leq x \leq a_3 \\ \frac{1}{4}+\frac{1}{2}\left(\frac{x-a_3}{a_4-a_3}\right), & a_3 \leq x \leq a_4 \\ 1, & a_4 \leq x \leq a_5 \\ 1-\frac{1}{4}\left(\frac{x-a_5}{a_6-a_5}\right), & a_5 \leq x \leq a_6 \\ 1-\frac{1}{2}\left(\frac{x-a_6}{a_7-a_6}\right), & a_6 \leq x \leq a_7 \\ \frac{1}{4}\left(\frac{x-a_7}{a_8-a_7}\right), & a_7 \leq x \leq a_8 \\ 0\ , & x > a_8 \end{cases}$$

Definition 2.4A fuzzy linguistic terms is a variable; this value is a represented word or sentence in natural language instead of a crisp number.

TheoremLet $\tilde{O}_1 = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8)$ and $\tilde{O}_2 = (b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8)$ be two OFN. The addition, subtraction, multiplication operations of $\tilde{O}_1$ and $\tilde{O}_2$, express by $\tilde{O}_1 \oplus \tilde{O}_2$, $\tilde{O}_1 \Theta \tilde{O}_2$ and $\tilde{O}_1 \otimes \tilde{O}_2$ appropriately, yield another OFN.

(i) $\tilde{O}_1 \oplus \tilde{O}_2 = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4, a_5 + b_5, a_6 + b_6, a_7 + b_7, a_8 + b_8,)$

(ii) $\tilde{O}_1 \Theta \tilde{O}_2 = (a_1 - b_1, a_2 - b_2, a_3 - b_3, a_4 - b_4, a_5 - b_5, a_6 - b_6, a_7 - b_7, a_8 - b_8)$

(iii) $k \otimes \tilde{O}_1 = (ka_1, ka_2, ka_3, ka_4, ka_5, ka_6, ka_7, ka_8)$ $k > 0$ a crisp number

(iv) $\tilde{O}_1 \otimes \tilde{O}_2 = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3, a_4 \times b_4, a_5 \times b_5, a_6 \times b_6, a_7 \times b_7, a_8 \times b_8)$

3. EXTENDED TOPSIS METHOD

This section provides the extension of TOPSIS under fuzzy environment.

Step 1: build fuzzy decision matrix, then finding fuzzy weights for all criteria.

Let's assume there are k participants in the decision-making group. The prominence of the criteria and then evaluation of alternatives are determined by

$$\tilde{x}_{ij} = \frac{1}{K}[x_{ij}^1 + x_{ij}^2 + \ldots + x_{ij}^K]$$

$$\tilde{w}_{ij} = \frac{1}{K}[w_{ij}^1 + w_{ij}^2 + \ldots + w_{ij}^K]$$

Where $\tilde{w}_j^K$ is the weights of the criteria and $\tilde{x}_{ij}^K$ is the value of the criteria given by K^{th} decision maker (DM).

The above fuzzy MCDM could be written in matrix form in the following way

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix},$$

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n]$$

Where $\tilde{x}_{ij}$, $i = 1, 2, \ldots m,$ $j = 1, 2, \ldots, n$ and $\tilde{w}_j$ are LV that arecharacterized by OFN using table-1.

Alternative Rating	**Fuzzy Number**
No Influence (NI)	(0, 0, 0, 0.06,0.12,0.18,0.24,0.3)
Very Low (VL)	(0.06, 0.12, 0.18, 0.24, 0.3,0.36,0.42,0.48)
Low (L)	(0.24, 0.3, 0.36, 0.42, 0.48, 0.54,0.6,0.66)
Medium (M)	(0.42, 0.48, 0.54, 0.6, 0.66, 0.72,0.78,0.84)
High (H)	(0.6, 0.66, 0.72, 0.78, 0.84, 0.9,0.94,0.99)
Very High (VH)	(0.78, 0.84, 0.9, 0.94,0.99,1, 1, 1)
Quality Rating Weight	**Fuzzy Number**
No Influence (NI)	(0, 0, 0, 0.06,0.12,0.18,0.24,0.3)
Very Low (VL)	(0.06, 0.12, 0.18, 0.24, 0.3,0.36,0.42,0.48)
Low (L)	(0.24, 0.3, 0.36, 0.42, 0.48, 0.54,0.6,0.66)
Medium (M)	(0.42, 0.48, 0.54, 0.6, 0.66, 0.72,0.78,0.84)
High (H)	(0.6, 0.66, 0.72, 0.78, 0.84, 0.9,0.94,0.99)
Very High (VH)	(0.78, 0.84, 0.9, 0.94,0.99,1, 1, 1)

Table 1: Linguistic variable and scale

Step 2: Normalized decision matrix $\tilde{R} = [\tilde{r}_{ij}]_{m\times n}$ can be calculated from $\tilde{D}$ in two ways,

$$\tilde{r}_{ij} = (a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8) \div \max_i a_8,\ j \in B\ \ \tilde{r}_{ij} = \min_i a_1 \div (a_1, a_2, a_3, a_4, a_5, a_6),\quad j \in C$$

Where$B$ and C are cost criteria and benefit criteria respectively.

Step 3: By constructing a weighted normalised decision matrix, $\tilde{V} = [\tilde{v}_{ij}]_{m\times n},\quad i = 1, 2, ...m,\quad j = 1, 2, ..., n$, where $\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_j$

Step 4: Fuzzy positive ideal solution and fuzzy negative ideal solution are determined by

$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, ..., \tilde{v}_n^+)$ and $A^- = (\tilde{v}_1^-, \tilde{v}_2^-, ..., \tilde{v}_n^-)$,

Where $\tilde{v}_j^+ = \left((\max(\tilde{v}_{ij}^8), \max(\tilde{v}_{ij}^8), ..., \max(\tilde{v}_{ij}^8)\right)$ and $\tilde{v}_j^- = \left((\min(\tilde{v}_{ij}^1), \min(\tilde{v}_{ij}^1), ..., \min(\tilde{v}_{ij}^1)\right)$,

$j = 1, 2, ..., n$.

Step 5: The separation between FPIS and FNIS and each of the criteria is determined as follows:

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+),\ i = 1, 2, ..., m$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-),\ i = 1, 2, ..., m$$

The distance can be calculated by

$$d(\tilde{A},\tilde{B})=\sqrt{\frac{1}{6}\left((a_1-b_1)^2+(a_2-b_2)^2+\ldots+(a_8-b_8)^2\right)}$$

Step 6: Determine the coefficient of closeness for all criterion.

$$CC_i=\frac{d_i^-}{d_i^+ + d_i^-},\ i=1,2,\ldots,m$$

Step 7: Based on closeness coefficient valuesR_i, ranking will be assigned to all criteria.

4. ADAPTATION OF THE PROBLEM TO THE MODEL

Obesity is a complex disease which involves excess amount of body fat. Obesity leads to chronic non epidemic diseases such as type 2 diabetes, Heart disease, Cancer and Alzheimer's disease; hence public health actions are needed to reduce its impact. Therefore, this present study is to Assessing Obesity Risk in a Comprehensive Range of Disease Factors Here, the following 12 disease and the six important factors are chosen for our study. The important factors are given, $Đ_1$- Allergies, $Đ_2$-Amoegas,$Đ_3$- Obesity, $Đ_4$- Cancer, $Đ_5$- Diabetes, $Đ_6$- Tuberculosis, $Đ_7$-Gastritis, $Đ_8$- Kidney Pain, $Đ_9$- Asthma, $Đ_{10}$- Hepatitis $Đ_{11}$- High Blood Pressure, $Đ_{12}$- Heart Attack, The important criteria are $ʒ_1$- Junk Food, $ʒ_2$- Smoke and Liquor, $ʒ_3$ Physical inactivity, $ʒ_4$- Overeating, $ʒ_5$- Genetics, $ʒ_6$- Stress, Emotional Factors and Poor Sleep.

First, the Decision Matrix was constructed with the help of three distinct experts using the proposed algorithm. (Given in Table-2, 3).

After that, convert the linguistic variable to octagonal fuzzy number and average them. The decision matrix is then normalized, and a weighted normalized matrix is constructed by multiplying the weighted and normalized matrices. Finally, in table-4, the difference between FPIS and FNIS for each alternative, as well as the closeness coefficient of each alternative, is computed. There are three experts are doctor, education parsons and common people they gave valuable suggestion correlation about disease and factor given below table 2.Reviews from E_1,$E_2$and E_3 are aggregating all three matrix Decision Makers with respect to criterion.

Disease\Factor	$ʒ_1$	$ʒ_2$	$ʒ_3$	$ʒ_4$	$ʒ_5$	$ʒ_6$
$Đ_1$	MI	HI	MI	HI	HI	VI
$Đ_2$	MI	MI	HI	HI	HI	LI
$Đ_3$	VHI	VHI	VHI	VHI	VHI	LI
$Đ_4$	VHI	MI	HI	HI	HI	LI
$Đ_5$	HI	MI	HI	HI	HI	LI
$Đ_6$	HI	MI	HI	HI	HI	LI
$Đ_7$	MI	MI	HI	HI	MI	LI
$Đ_8$	MI	MI	HI	HI	HI	LI

Đ$_{9}$	VHI	HI	VHI	VHI	HI	VLI
Đ$_{10}$	HI	HI	VHI	MI	HI	LI
Đ$_{11}$	MI	HI	HI	HI	MI	VLI
Đ$_{12}$	HI	MI	HI	HI	HI	LI

Table 2: Reviews from E_1,E_2 and E_3 Decision Makers with respect to criteria

	E_1	E_2	E_3
ʒ$_1$	MI	HI	HI
ʒ$_2$	HI	MI	MI
ʒ$_3$	MI	HI	MI
ʒ$_4$	HI	HI	MI
ʒ$_5$	MI	MI	HI
ʒ$_6$	LI	VLI	LI

Table 3: Weightage of the criteria's according to decision makers.

Step 1: build fuzzy decision matrix, then finding fuzzy weights for all criteria.

Disease\Factor	ʒ$_1$	ʒ$_2$	ʒ$_3$	ʒ$_4$	ʒ$_5$	ʒ$_6$
Đ$_{1}$	5.04	6.43	6.91	6.43	6.43	2.16
Đ$_{2}$	5.04	5.04	6.43	6.43	6.43	4.14
Đ$_{3}$	6.91	6.91	6.91	6.91	6.91	4.14
Đ$_{4}$	6.91	5.04	6.43	6.43	6.43	4.14
Đ$_{5}$	6.43	5.04	6.43	6.43	6.43	4.14
Đ$_{6}$	6.43	5.04	6.43	6.43	6.43	4.14
Đ$_{7}$	5.04	5.04	6.43	6.43	5.04	4.14
Đ$_{8}$	5.04	5.04	6.43	6.43	6.43	4.14
Đ$_{9}$	6.91	6.43	6.91	6.91	6.43	2.16
Đ$_{10}$	6.43	6.43	6.91	5.04	6.43	4.14
Đ$_{11}$	5.04	6.43	6.43	6.43	5.04	2.16
Đ$_{12}$	6.43	5.04	6.43	6.43	6.43	4.14

Step 2: Normalized decision matrix $\tilde{R} = [\tilde{r}_{ij}]_{m\times n}$ can be calculated from $\tilde{D}$

Disease\Factor	ʒ$_1$	ʒ$_2$	ʒ$_3$	ʒ$_4$	ʒ$_5$	ʒ$_6$
Đ$_{1}$	0.241474	0.325204	0.302514	0.289592	0.296387	0.166522
Đ$_{2}$	0.241474	0.254904	0.2815	0.289592	0.296387	0.319168
Đ$_{3}$	0.331069	0.349481	0.302514	0.31121	0.318513	0.319168
Đ$_{4}$	0.331069	0.254904	0.2815	0.289592	0.296387	0.319168

Đ$_5$	0.308071	0.254904	0.2815	0.289592	0.296387	0.319168
Đ$_6$	0.308071	0.254904	0.2815	0.289592	0.296387	0.319168
Đ$_7$	0.241474	0.254904	0.2815	0.289592	0.232316	0.319168
Đ$_8$	0.241474	0.254904	0.2815	0.289592	0.296387	0.319168
Đ$_9$	0.331069	0.325204	0.302514	0.31121	0.296387	0.166522
Đ$_{10}$	0.308071	0.325204	0.302514	0.22699	0.296387	0.319168
Đ$_{11}$	0.241474	0.325204	0.2815	0.289592	0.232316	0.166522
Đ$_{12}$	0.308071	0.254904	0.2815	0.289592	0.296387	0.319168

Step 3: By constructing a weighted normalized decision matrix.

Disease\Factor	Ʒ$_1$	Ʒ$_2$	Ʒ$_3$	Ʒ$_4$	Ʒ$_5$	Ʒ$_6$
Đ$_1$	0.043465	0.078049	0.090754	0.104253	0.124483	0.079931
Đ$_2$	0.043465	0.061177	0.08445	0.104253	0.124483	0.1532
Đ$_3$	0.059592	0.083875	0.087729	0.112036	0.133775	0.1532
Đ$_4$	0.059592	0.061177	0.08445	0.104253	0.124483	0.1532
Đ$_5$	0.055453	0.061177	0.08445	0.104253	0.124483	0.1532
Đ$_6$	0.055453	0.061177	0.08445	0.104253	0.124483	0.1532
Đ$_7$	0.043465	0.061177	0.08445	0.104253	0.097573	0.1532
Đ$_8$	0.043465	0.061177	0.08445	0.104253	0.124483	0.150009
Đ$_9$	0.059592	0.078049	0.090754	0.112036	0.124483	0.079931
Đ$_{10}$	0.055453	0.078049	0.090754	0.081716	0.124483	0.1532
Đ$_{11}$	0.043465	0.078049	0.08445	0.104253	0.097573	0.079931
Đ$_{12}$	0.055453	0.061177	0.08445	0.104253	0.124483	0.150009

Step 4: Fuzzy positive ideal solution and fuzzy negative ideal solution are determined

V+	0.059592	0.083875	0.090754	0.112036	0.133775	0.1532
V-	0.043465	0.061177	0.08445	0.081716	0.097573	0.079931

Step 5: The separation between FPIS and FNIS and each of the criteria is determined.

SI+	0.0762	0.031	0.003	0.0264	0.0268	0.0248	0.0467	0.0311	0.0741	0.0325	0.0841	0.0271
SI-	0.0394	0.0812	0.0915	0.7677	0.0821	0.0821	0.0766	0.0783	0.0472	0.0809	0.0281	0.0792

Step 6: Determine the coefficient of closeness for all criterion

Disease	$Đ_1$	$Đ_2$	$Đ_3$	$Đ_4$	$Đ_5$	$Đ_6$	$Đ_7$	$Đ_8$	$Đ_9$	$Đ_{10}$	$Đ_{11}$	$Đ_{12}$
Ri	0.341	0.723	0.968	0.966	0.753	0.767	0.621	0.715	0.389	0.713	0.250	0.745

Step 7: Based on closeness coefficient values R_i, ranking will be assigned to all criteria.

Then calculate the distance of each alternative from FPIS and FNIS and closeness coefficient of each alternative.

Disease	R_i	Rank
$Đ_1$	0.341	11
$Đ_2$	0.723	6
$Đ_3$	0.968	1
$Đ_4$	0.966	2
$Đ_5$	0.753	4
$Đ_6$	0.767	3
$Đ_7$	0.621	9
$Đ_8$	0.715	7
$Đ_9$	0.389	10
$Đ_{10}$	0.713	8
$Đ_{11}$	0.250	12
$Đ_{12}$	0.745	5

Table 4: Closeness Coefficient of each alternative

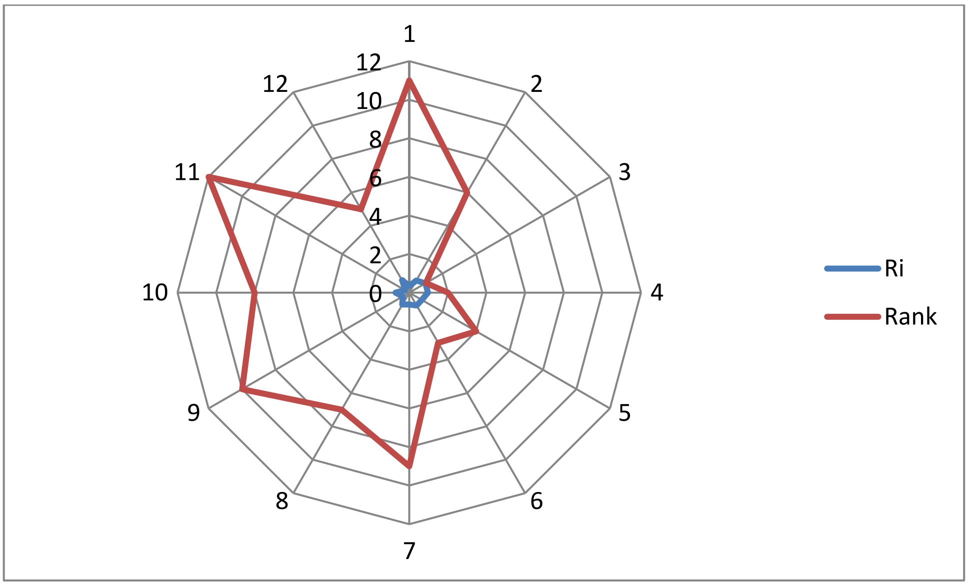

Fig 1: Closeness Coefficient.

5. RESULT AND DISCUSSION

First, the decision matrix is constructed with the help of three distinct experts to give their opinions. The decision matrix is then normalized, and a weighted normalized matrix is constructed. After that, FPIS and FNIS is determined and ranking is given to all the factors by calculating closeness coefficient values.From Table 4, the ranking of disease factors is D3> D9> D10> D12> D4> D8> D5> D2>D11> D1> D7> D6. It is clear from the ranking that D3-Obesityplays a major role among the remaining important factors andFigure 1 depicts the closeness coefficient values and ranking of the factors.

6. CONCLUSION

In this study, TOPSIS approach is extended using octagonal fuzzy numbers. Moreover, their arithmetic operations, as well as linguistic values are derived. The proposed method is then applied to analyze therisk factors. After ranking, it is determined that D3- Obesity plays crucial role in developing many health complications in human body. Hence, one needs to concentrate those factors to reduce the risks.

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