Evaluation Multi Diabetes Mellitus Symptoms by Integrated Fuzzy-based MCDM Approach

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Abstract: Currently, diabetes is one of the most dangerous diseases spreading among people around the world. The most prominent reasons for the spread of this type of the disease are social, behavioral and medical factors. Different types of diabetes mellitus affecting both men and women were discussed by researchers. Various symptoms caused to the disease was determined by physicians. These symptoms were classified as criteria in this study according to the literature. The paper aims to evaluation preferences of the diabetes symptoms for patients by adapting decision-making techniques. Multiple criteria decision-making techniques were used to solve the decision-making problems in this study. The study methodology consists of three stags; 1) Determine multi criteria of diabetes mellitus symptoms according to the literature; 2) Calculation of parameter weights using triangular fuzzy numbers approach; 3) Selection the best and worst alternative of diabetes patients by applying the fuzzy-technique of order preference similarity to the ideal solution (TOPSIS) method according to the multiple symptoms. Results were obtained from selecting the best patient at (P248), while the worst patient was identified at (P333). Hence, this study may assist patients and doctors in taking appropriate measures aimed at reducing the incidence of diabetes.

Keywords: Diabetes Mellitus Symptoms, Triangular Fuzzy Numbers, TOPSIS, MCDM

1. Introduction

Nowadays, diabetes mellitus is a widely spread disease among humans around the world. Diabetes mellitus is a disease that affects all people and all ages' stages that causes variation in blood sugar levels due to a disorder of the glands that secrete insulin in the body [1]. Many symptoms that may increase the rate of diabetes due to lack of exercise and a change in eating habits. These symptoms are currently considered one of the main causes of non-communicable diseases [2]. Previously, the number of people with diabetes in humans ranged between ages (20-79) years, while now even people at an early age have become vulnerable to developing it [3].

The results of the International Diabetes Federation (IDF) reported in the year 2019, there is a potential increase in the number of deaths among adults and elderly people with diabetes mellitus between the ages of 65 and 99. In addition to the increased mortality among adults with diabetes aged 20 to 79 years. As well as, global estimates predict the incidence, increasing of deaths with type- 1 diabetes in children and adolescents and the prevalence of hyperglycemia during pregnancy in 2019 and beyond [3].

According to the Annual reports of the World Health Organization (WHO), about 422 million people are infected by diabetes mellitus around the world. The majority of people with this disease live in low- and middle-income regions. In addition, the death rate from diabetes has reached 1.6 million deaths annually. Consequently, the incidence of diabetes has steadily increased over the past few decades [4].

Several approaches have presented to identify the symptoms which causing diabetes among people. Some studies have provided solutions to the problem of diagnosing diabetes symptoms using artificial intelligence techniques. The process of determining symptoms of diabetes Mellitus in its early stages is important for disease control. A new approach to the early diagnosis of disease using a fuzzy inference system has been proposed. In addition to diagnosing symptoms, this system also provides recommendations for treatment [5]. The F-Score feature selection is utilized with the Fuzzy Support Vector Machine (FSVM) method for the dataset to classify and detect diabetes mellitus. The dataset is trained using the SVM method to generate fuzzy rules and applying the fuzzy inference process to classify the outputs for diabetic patients [6]. A new approach proposed to determine the risk factors of the diabetes mellitus using range dominate fuzzy prediction (RDFP) method for diagnosing the disease in its early stages. The ranking of outputs using the proposed RDFB method to identify the high and low the risk levels of patients by diabetes and assist clinicians to diagnose the disease [7]. Risk factors causing some complications for diabetic patients were identified by integrating the fuzzy system with two multi-criteria decision methods. Fuzzy TOPSIS method and fuzzy Grey Relational Analysis (GRA) method used to determine diabetes complications [8].

The paper organized following as section 1, the introduction discusses the diabetes mellitus risk. Section 2, discuss the methodology proposed to solve diabetes mellitus symptoms problem. Section 3, discussion of the results. Section 4, conclusion.

2. Overview of Diabetes Mellitus

There are three main types of diabetes mellitus spread around the world. Diabetes is a disease that indicates the level of glucose in the human body. Glucose is the main source of energy that the cells of the body need. Level of glucose is maintained by insulin which is secreted by the pancreas. Therefore, to maintain the level of glucose in the body, the level of insulin secreted by the pancreas is determined [5], [7],[8], [9].

The most important types of diabetes Mellitus:

1. Type 1 Diabetes (T1D): Often the pancreas produces little amount of insulin required for body or no insulin developed type -1 diabetes (insulin-dependent)
2. Type 2 diabetes (T2D): the body often does not use insulin, developed type 2 diabetes (insulin-independent).
3. Gestational Diabetes: Pregnant women often get this type of diabetes during pregnancy period.

3. Materials and Methods

This section discusses the proposed methodology for solving the diabetes mellitus risk problem using multi-criteria decision-making methods. Many research has adopted these methods to solve the problem of conflict of criteria with different such as healthcare, education, and industry sectors [10],[11],[12]. This methodology using a triangular fuzzy number approach to evaluate several of diabetes mellitus symptoms. As well as, using a fuzzy-TOPSIS method to select between patients of diabetes mellitus based on different symptoms. The methodology applied in three stages: the first stage, eight criteria determined different symptoms as age, pregnancies, glucose blood pressure, skin thickness, insulin, body mass index, and diabetes pedigree function obtained from large scale data [13]. The second stage, adapting the triangular fuzzy number approach to evaluate eight criteria based on the decision-maker. Finally, the best and worst alternatives selected using the fuzzy-TOPSIS method according to the 768 patients. MCDM techniques are adopted to solve decision-making problems for diabetes mellitus symptoms in this study. See figure 1, illustrated proposed framework for selection diabetes mellitus alternatives.

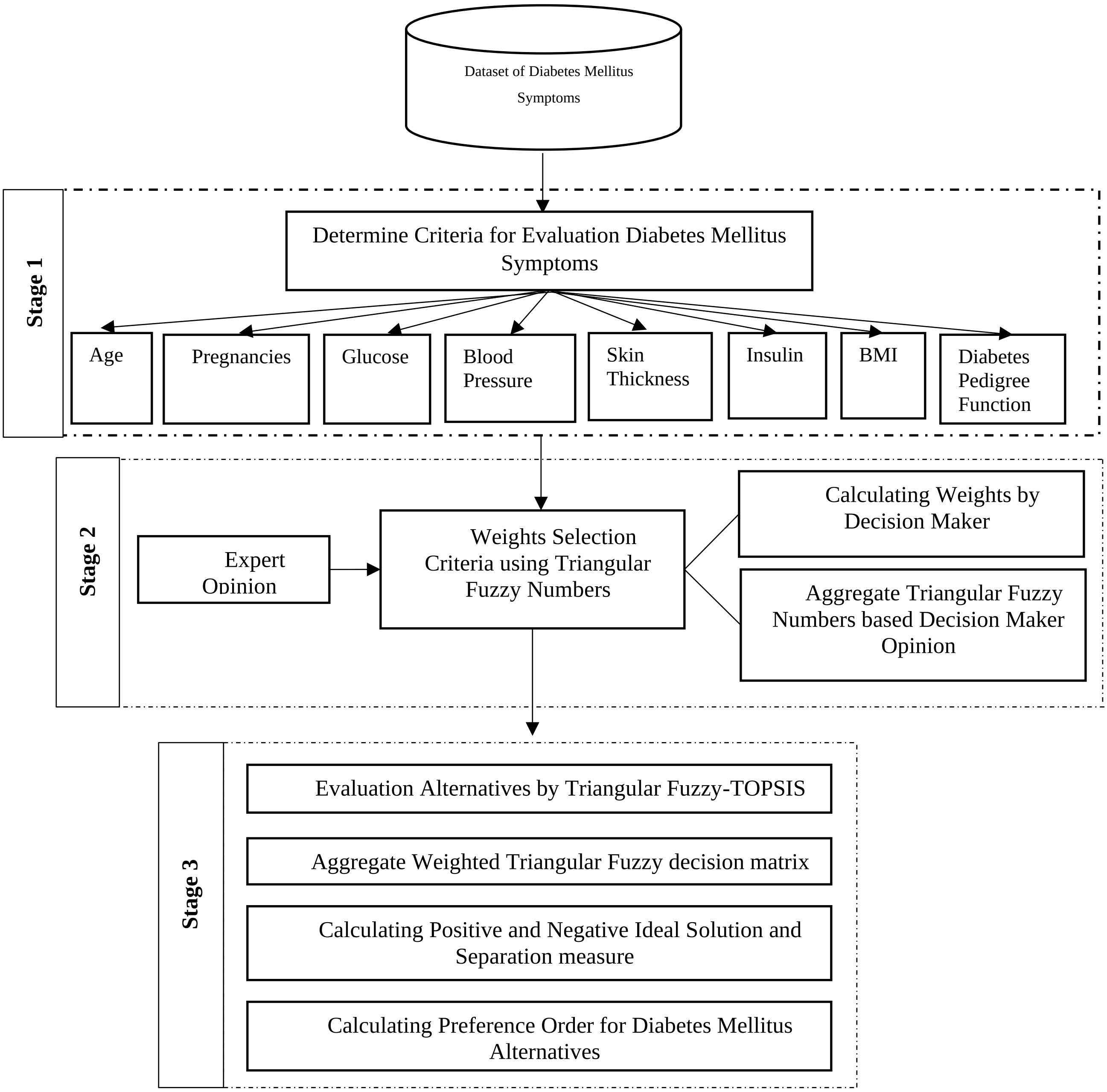

Figure.1 proposed framework for selection diabetes mellitus alternatives

3.1 Triangular Fuzzy Number

L.Zadeh [14] proposed a fuzzy set theory or probability theory based on the concept of probability distribution as ambiguous variables. This theory based on flexible vague constraints of values that can be assigned to a particular variable. The fuzzy logic theory was applied in different studies to solve different issues as in the industry, health care and education sectors [15],[16].

A triangular fuzzy number included three elements $\tilde{\boldsymbol{a}} = \left(\boldsymbol{a}^{l}, \boldsymbol{a}^{m}, \boldsymbol{a}^{u}\right)$ as a membership function can be defined as follows: [17] ,[18].

Triangular Fuzzy Numbers $\tilde{\boldsymbol{a}} = \left(\boldsymbol{a}^{l}, \boldsymbol{a}^{m}, \boldsymbol{a}^{u}\right)$ (1)

$$\mu\, \tilde{a}\, (x) = \begin{cases} (x - a_l) \;/\; (a_m - a_l) & if\ a_l \le x \le a_m \\ (a_u - x) \;/\; (a_u - a_m) & if\ a_m \le x \le a_u \\ 0, & Otherwise. \end{cases}$$

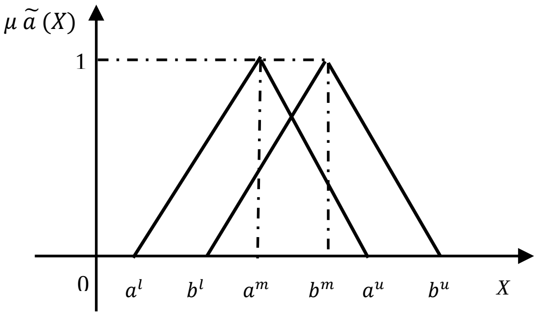

Figure. 2 triangular fuzzy number procedure

The triangular fuzzy number represented as triple values as in the figure 2.
Where, the a^l represent a lower number, a^m represent a moderate number and a^u represent an upper number then $a^l \leq a^m \leq a^u$,and if the $a^l = a^m = a^u$ after that the $\tilde{a}$ could be a crisp number.
Fuzzy values are represented in two matrix using triangular fuzzy numbers as $\tilde{a} = (a^l, a^m, a^u)$ and $\tilde{b} = (b^l, b^m, b^u)$
where $\tilde{a} > 0$ *and* $\tilde{b} > 0$ which implemented in different arithmetic formulas as following:[8] ,[19]

1- Addition formula:
$$\tilde{a} + \tilde{b} = (a^l + b^l,\ a^m + b^m, a^u + b^u) \qquad (2)$$

2- Subtraction formula:
$$\tilde{a} - \tilde{b} = (a^l - b^l,\ a^m - b^m, a^u - b^u) \qquad (3)$$

3- Multiplication formula:
$$\tilde{a} * \tilde{b} = (a^l * b^l,\ a^m * b^m, a^u * b^u) \qquad (4)$$

4- Division formula:
$$\tilde{a} / \tilde{b} = (a^l / b^U,\ a^m / b^m, a^u / b^l) \qquad (5)$$

5- Inverse
$$\frac{1}{\tilde{a}} = \frac{1}{(a^l + a^m, + a^u)} = (\frac{1}{a^l} + \frac{1}{a^m} + \frac{1}{a^u}) \qquad (6)$$

The triangular fuzzy numbers $\tilde{A} = (a^l, a^m, a^u\ )$ this matrix included a triples elements as follows:

$$\tilde{A} = \begin{bmatrix} a_{11}^l, a_{11}^m, a_{11}^u & \cdots & a_{1n}^l, a_{1n}^m, a_{1n}^u \\ \vdots & \ddots & \vdots \\ a_{m1}^l, a_{m1}^m, a_{m1}^u & \cdots & a_{mn}^l, a_{mn}^m, a_{mn}^u \end{bmatrix} \qquad (8)$$

Let the matrix $\tilde{A}$ be an (m × n) represented in triangular fuzzy elements. This matrix can be a reciprocal form when the condition is satisfied:

$$\tilde{a}_{ij} = \left(a_{ij}^l, a_{ij}^m, a_{ij}^u\right) \qquad (9)$$

$$\tilde{a}_{ij} = \left(\frac{1}{a_{ij}^l}, \frac{1}{a_{ij}^m}, \frac{1}{a_{ij}^u}\right) \qquad (10)$$

where the $i,j = 1,2,\ldots\ldots, n$

$$\tilde{A} = \begin{bmatrix} (1,\ 1,\ 1) & \left(a_{ij}^l, a_{ij}^m, a_{ij}^u\right) \cdots & \left(a_{ij}^l, a_{ij}^m, a_{ij}^u\right) \\ \left(\frac{1}{a_{ij}^l}, \frac{1}{a_{ij}^m}, \frac{1}{a_{ij}^u}\right) \vdots & (1,\ 1,\ 1)\ \ddots & \left(a_{ij}^l, a_{ij}^m, a_{ij}^u\right) \vdots \\ \left(\frac{1}{a_{ij}^l}, \frac{1}{a_{ij}^m}, \frac{1}{a_{ij}^u}\right) & \left(\frac{1}{a_{ij}^l}, \frac{1}{a_{ij}^m}, \frac{1}{a_{ij}^u}\right) \cdots & (1,\ 1,\ 1) \end{bmatrix} \qquad (11)$$

Where $0 < a_{ij}^l < a_{ij}^m < a_{ij}^u$, $i,j = 1,2,\ldots.., n$.

Table. 1. Triangular fuzzy number

Description of scales	Triangular Fuzzy number
Equal favors	(1,1,1)
Slightly favors	(2,3,4)
Strong favors	(4,5,6)
Very strong favors	(6,7,8)
Extremely favors	(9,9,9)

The linguistic values of this matrix converted to the triangular fuzzy numbers.

Table. 2. Decision matrix stricture

Criteria / Alternative	Age	Pregnancies	Glucose	Blood Pressure	Skin Thickness	Insulin	BMI	Diabetes Pedigree Function
Alternative 1	A v (A1/Ts)	P v (A1/ TS)	G v (A1/ Ts)	B.P v (A1/ Ts)	S.T v (A1/Ts)	I v (A1/Ts)	B.I.M v (A1/ Ts)	D.P.F v (V1/ Ts)
Alternative 2	A v (A2/Ts)	P v (A2/ TS)	G v (A2/ Ts)	B.P v (A2/ Ts)	S.T v (A2/Ts)	I v (A2/Ts)	BIM v (A2/ Ts)	DPF v (V2/Ts)
Alternative 3	A v (A3/Ts)	P v (A3/ TS)	G v (A3/ Ts)	B.P v (A3/ Ts)	S.T v (A3/Ts)	I v (A3/Ts)	BIMv (A3/ Ts)	DPF v (V3/ Ts)
Alternative 4	A v (A4/Ts)	P v (A4/ TS)	G v (A4/ Ts)	B.P v (A4/ Ts)	S.T v (A4/Ts)	I v (A4/Ts)	BIM v (A4/ Ts)	DPF v (V4/ Ts)
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Alternative n	A v (An/Ts)	P v (An/ TS)	G v (An/ Ts)	B.P v (An/ Ts)	S.T v (An/Ts)	I v (An/ Ts)	BIM v (An/ Ts)	DPF v (Vn/ Ts)

Av: Age value
P v: Pregnancies value
G v: Glucose value
B.P v: Blood Pressure value
S.T v: Skin Thickness value
I v: Insulin value
B.M.I v: BMI value
D.P.F v: Diabetes Pedigree Function

A: Alternatives
Ts : Test sample
n: Number of Alternatives

3.2 Fuzzy-TOPSIS method

The Fuzzy- TOPSIS method is applied, which considered a proper method established by Hwang and Yoon in 1981. In addition, other improvements were made by Yoon in 1987[20],[21]. In this method, the correct selection is chosen based on calculating the geometric mean of the positive ideal order and calculating the largest geometric separation for the negative ideal order [22].

Step1: Fuzzy TOPSIS can be briefly expressed in the matrix using Eqs.(12) and (13) [23],[19].

$$\tilde{D} = \begin{matrix} \\ A1 \\ A2 \\ A3 \\ \cdots \\ Am \end{matrix} \begin{matrix} C1 & C2 & \ldots & Cn \\ \left[\begin{matrix} \tilde{x}11 & \tilde{x}12 & \ldots & \tilde{x}1n \\ \tilde{x}21 & \tilde{x}22 & \ldots & \tilde{x}2n \\ \tilde{x}31 & \tilde{x}32 & \ldots & \tilde{x}3n \\ \vdots & \vdots & \ddots & \\ \tilde{x}m1 & \tilde{x}m2 & \ldots & \tilde{x}mn \end{matrix}\right] \end{matrix} \qquad (12)$$

$\widetilde{W}$ = [$\widetilde{w}1, \widetilde{w}2, \widetilde{w}3,...., \widetilde{w}n$] (13)

Where $\tilde{x}ij$, i= 1,2,…., m , j= 1,2,…, n and $\widetilde{w}j$, j = 1,2,…,n are linguistic triangular fuzzy numbers, $\tilde{x}ij$ =(l_{ij}, m_{ij},u_{ij}).

Step2: Representing a normalized fuzzy decision matrix namely $\tilde{R}$ is formulated as in Eq (14).

$$\tilde{R} = [\tilde{x}\ ij\ ]\ (m \times n) \quad (14)$$

Step3: Selection the linguistic Triangular fuzzy number ratings, $\tilde{x}ij$, *i* = 1,2,…., *m* , *j* = 1,2,…, *n* used for alternatives based on criteria and the appropriate linguistic variables, as well as the $\widetilde{w}j$, *j* = 1,2,…,*n* for criteria weight.

Step4: Creation the weighted fuzzy normalized of the decision matrix. The weighted fuzzy normalized value represented in the DM using Eq. (15).

$$\tilde{V} = \begin{bmatrix} \widetilde{w}1\,\tilde{r}11 & \widetilde{w}2\,\tilde{r}12 & \ldots.. & \widetilde{w}j\,\tilde{r}1j & \ldots.. & \widetilde{w}1\,\tilde{r}1n \\ \widetilde{w}2\,\tilde{r}21 & \widetilde{w}2\,\tilde{r}22 & \ldots.. & \widetilde{w}j\,\tilde{r}2j & \ldots.. & \widetilde{w}2\,\tilde{r}2n \\ \vdots & \vdots & & \vdots & & \vdots \\ \widetilde{w}1\,\tilde{r}i1 & \widetilde{w}2\,\tilde{r}i2 & \ldots.. & \widetilde{w}j\,\tilde{r}i2 & \ldots.. & \widetilde{w}2\,\tilde{r}in \\ \vdots & \vdots & & \vdots & & \vdots \\ \widetilde{w}1\,\tilde{r}m1 & \widetilde{w}2\,\tilde{r}m2 & \ldots.. & \widetilde{w}j\,\tilde{r}mj & \ldots.. & \widetilde{w}j\,\tilde{r}mn \end{bmatrix} \quad (15)$$

Step5: Calculation triangular fuzzy- positive-ideal solution (FPIS, A*) and the triangular fuzzy- negative-ideal solution (FNIS,A^-) represented in Eqs. (16) and (17).

$$A^* = (\ \tilde{v}_1^*\ , \tilde{v}_2^*, \ldots., \tilde{v}_n^*\ )$$

$$= \{\ (max_i\ v_{ij}\ |\ i = 1,2,\ldots, m)\ , j = 1, 2,\ldots, \text{n}\} \quad (16)$$

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

$$= \{\ (min_i\ v_{ij}\ |\ i = 1,2,\ldots, m)\ , j = 1, 2,\ldots, \text{n}\} \quad (17)$$

Step6: Calculation of separation scale. Calculating the distance for each alternative based (A* and A-) measure using Eqs. (18) and (19).

$$d_i^* = \sum_{j=1}^{n} d\ \ (\tilde{v}_{ij}^*, v_j^*\ ),\ i = 1,2,\ \ldots., m \quad (18)$$

$$d_i^- = \sum_{j=1}^{n} d\ \ (\ \tilde{v}_{ij}^-\ , v_j^-\ ),\ i = 1,2,\ \ldots., m \quad (19)$$

Step7: Calculation of closeness coefficient and similarity to the ideal solution. This step applied for calculating the closeness coefficient and similarity to an ideal solution using Eq. (20):

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*} \quad (20)$$

Step 6: Calculation of the ranking of alternatives. This step applied to select an alternative based on the maximum CC_i^* or calculating the ranking of alternatives using CC_i^* in descending order.

4. Results and Discussion

In this section, the results of this study were obtained by combining the fuzzy system with the TOPSIS method. The triangular fuzzy numbers applied to calculate the weights of the criteria in the case study. Table 3, shows the conversion of linguistic values into triangular fuzzy numbers. As well as, table 4, illustrate the calculation of weights for the values of the criteria that were determined based on the opinions of three experts according to the formula of the triangular fuzzy numbers. In order to obtain single values for each criterion, the triangular fuzzy numbers0 values are collected according to the opinion of the experts, as shown in Table 5. Hence, the weights of the criteria which selected will be used with the normalization data using TOPSIS technique in the next section.

Table. 3. Linguistic triangular fuzzy number

Description Score	Score	Triangular Fuzzy Number		
Extremely low	EL	0	0	0.1
Very low	VL	0	0.1	0.3
Low	L	0.1	0.3	0.5
Medium	M	0.3	0.5	0.7
High	H	0.5	0.7	0.9
Very high	VH	0.7	0.9	1
Extremely high	EH	0.9	1	1

Table. 4. Determined fuzzy weights of criteria

Criteria	DM1			DM2			DM3		
Age	0.3	0.5	0.7	0.7	0.9	1	0.1	0.3	0.5
Pregnancies	0.9	1	1	0.3	0.5	0.7	0.3	0.5	0.7
Glucose	0.7	0.9	1	0.1	0.3	0.5	0.1	0.3	0.5
Blood Pressure	0.7	0.9	1	0.1	0.3	0.5	0.7	0.9	1
Skin Thickness	0.7	0.9	1	0.1	0.3	0.5	0	0.1	0.3
Insulin	0.7	0.9	1	0.1	0.3	0.5	0.7	0.9	1
BMI	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7
Diabetes Pedigree Function	0.1	0.3	0.5	0.3	0.5	0.7	0.5	0.7	0.9

Table. 5. Aggregated triangular fuzzy decision matrix

Criteria	DM1	DM2		DM3
Age	0.37	0.57		0.73
Pregnancies	0.50	0.67		0.80
Glucose	0.30	0.50		0.67
Blood Pressure	0.50	0.70		0.83
Skin Thickness	0.27	0.43		0.60
Insulin	0.50	0.70		0.83
BMI	0.37	0.57		0.77
Diabetes Pedigree Function	0.30	0.50		0.70

In other hand, final results were obtained after applying the fuzzy TOPSIS method. The dataset was adapted for various patients with diabetes mellitus. The normalization values of the data were calculated according to formula 14, based on the appropriate linguistic variables. Table 6, shows the normalization values for the data set values based on the triangular fuzzy numbers. The weights of the criteria were calculated based on the triangular fuzzy numbers, which used with the normalization values of the data as in formula 15. Therefore, table 7, shows the weighted normalization values for the various criteria in this study. In another hand, the values of the positive ideal solution (FPIS), as well as the values of the negative ideal solution (FNIS), are determined according to the formulas (16, 17) respectively. In addition, distance values for each alternative are calculated based on the positive and negative ideal solution values previously obtained using the formulas (18, 19). As well as, the closeness coefficient and similarity to the ideal solution are calculated based on the formula (20). Finally, the ranking of all alternatives is calculated according to the maximum CC_i^* or calculating the ranking of alternatives using CC_i^* in descending order. The results showed the best alternative for the patient (P248), while the worst for the patient (P333) were developing to the debates Mellitus.

Table. 6. Shows normalized decision matrix for fuzzy TOPSIS analysis

Alternative	Age	Pregnancies	Glucose	Blood Pressure	Skin Thickness	Insulin	BMI	Diabetes Pedigree Function
P1	0.001959	0.000235	0.005797	0.00282	0.001371	0	0.001316	2.46E-05
…	…	…	…	…	…	…	…	…
P248	0.000901	0	0.006463	0.003525	0.001293	0.02664	0.002049	1.67E-05
P249	0.001332	0.0003525	0.004857	0.002742	0.001293	0.01575	0.001387	1.1E-05
P250	0.000901	3.917E-05	0.004348	0.003369	0.000744	0	0.001179	5.6E-06
P251	0.001645	0.0003525	0.004152	0.002037	0	0	0.001222	1.49E-05
P252	0.001058	7.834E-05	0.005053	0.00329	0	0	0.001097	1.11E-05
P253	0.00094	7.834E-05	0.003525	0.003134	0.000548	0.00215	0.000956	9.75E-06
P254	0.000979	0	0.003369	0.002664	0.001253	0	0.001402	9.32E-06
P255	0.001724	0.0004701	0.003604	0.002429	0.000274	0.01011	0.001081	3.63E-05
P256	0.000823	3.917E-05	0.004426	0.002507	0.001371	0	0.001316	2.13E-05
P257	0.001175	0.0001175	0.004348	0.002194	0.001528	0	0.001179	2.18E-05
…	…	…	…	…	…	…	…	…
P324	0.001684	0.0005092	0.005954	0.003525	0.001293	0.00114	0.00105	2.86E-05
P325	0.000823	7.834E-05	0.004387	0.002938	0.001253	0	0.001398	5.8E-06
P326	0.00094	3.917E-05	0.00615	0.00282	0.000823	0.00658	0.001003	4.82E-06
P327	0.001175	3.917E-05	0.004779	0.002507	0.001253	0.00611	0.001375	2.71E-05
P328	0.001449	0.0003917	0.007012	0.002742	0	0	0.001375	7.83E-06
P329	0.000901	7.834E-05	0.003995	0.003369	0.00141	0.0047	0.001782	4.97E-06
P330	0.001449	0.000235	0.004113	0.002742	0.001253	0.00266	0.001206	4.78E-06
P331	0.001802	0.0003134	0.004622	0.00282	0.000744	0	0.000905	5.78E-05
P332	0.000979	7.834E-05	0.003408	0.002272	0.000627	0.00204	0.001281	6.5E-06
P333	0.001606	3.917E-05	0.007051	0	0	0	0.001696	1.1E-05
…	…	…	…	…	…	…	…	…
P768	0.000901	3.917E-05	0.003643	0.002742	0.001214	0	0.001191	1.23E-05

Table. 7. Show the weighted normalize of decision matrix

Alternative	Age			Pregnancies			Glucose			Blood Pressure			Skin Thickness			Insulin			BMI			Diabetes Pedigree Function		
P1	7E-04	0.001	0.001	9E-05	1E-04	2E-04	0.002	0.003	0.004	0.001	0.002	0.002	4E-04	0.0006	8E-04	0	0	0	5E-04	7E-04	1E-03	7E-06	1E-05	2E-05
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
P248	3E-04	5E-04	7E-04	0	0	0	0.002	0.004	0.005	0.001	0.002	0.003	3E-04	0.0006	8E-04	0.01	0.015	0.02	8E-04	0.001	0.002	5E-06	8E-06	1E-05
P249	5E-04	8E-04	1E-03	1E-04	2E-04	3E-04	0.002	0.003	0.004	0.001	0.002	0.002	3E-04	0.0006	8E-04	0.006	0.009	0.012	5E-04	8E-04	0.001	3E-06	6E-06	8E-06
P250	3E-04	5E-04	7E-04	1E-05	2E-05	3E-05	0.002	0.002	0.003	0.001	0.002	0.002	2E-04	0.0003	4E-04	0	0	0	4E-04	7E-04	9E-04	2E-06	3E-06	4E-06
P251	6E-04	9E-04	0.001	1E-04	2E-04	3E-04	0.002	0.002	0.003	7E-04	0.001	0.001	0	0	0	0	0	0	4E-04	7E-04	9E-04	4E-06	7E-06	1E-05
P252	4E-04	6E-04	8E-04	3E-05	4E-05	6E-05	0.002	0.003	0.004	0.001	0.002	0.002	0	0	0	0	0	0	4E-04	6E-04	8E-04	3E-06	6E-06	8E-06
P253	3E-04	5E-04	7E-04	3E-05	4E-05	6E-05	0.001	0.002	0.003	0.001	0.002	0.002	1E-04	0.0002	3E-04	8E-04	0.001	0.002	4E-04	5E-04	7E-04	3E-06	5E-06	7E-06
P254	4E-04	6E-04	7E-04	0	0	0	0.001	0.002	0.002	1E-03	0.002	0.002	3E-04	0.0005	8E-04	0	0	0	5E-04	8E-04	0.001	3E-06	5E-06	7E-06
P255	6E-04	1E-03	0.001	2E-04	3E-04	3E-04	0.001	0.002	0.003	9E-04	0.001	0.002	7E-05	0.0001	2E-04	0.004	0.006	0.007	4E-04	6E-04	8E-04	1E-05	2E-05	3E-05
P256	3E-04	5E-04	6E-04	1E-05	2E-05	3E-05	0.002	0.003	0.003	9E-04	0.001	0.002	4E-04	0.0006	8E-04	0	0	0	5E-04	7E-04	1E-03	6E-06	1E-05	1E-05
P257	4E-04	7E-04	9E-04	4E-05	7E-05	9E-05	0.002	0.002	0.003	8E-04	0.001	0.002	4E-04	0.0007	9E-04	0	0	0	4E-04	7E-04	9E-04	7E-06	1E-05	2E-05
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
P326	3E-04	5E-04	7E-04	1E-05	2E-05	3E-05	0.002	0.003	0.005	0.001	0.002	0.002	2E-04	0.0004	5E-04	0.002	0.004	0.005	4E-04	6E-04	7E-04	1E-06	2E-06	3E-06
P327	4E-04	7E-04	9E-04	1E-05	2E-05	3E-05	0.002	0.003	0.004	9E-04	0.001	0.002	3E-04	0.0005	8E-04	0.002	0.003	0.004	5E-04	8E-04	0.001	8E-06	1E-05	2E-05
P328	5E-04	8E-04	0.001	1E-04	2E-04	3E-04	0.003	0.004	0.005	0.001	0.002	0.002	0	0	0	0	0	0	5E-04	8E-04	0.001	2E-06	4E-06	5E-06
P329	3E-04	5E-04	7E-04	3E-05	4E-05	6E-05	0.001	0.002	0.003	0.001	0.002	0.002	4E-04	0.0006	8E-04	0.002	0.003	0.003	7E-04	0.001	0.001	1E-06	2E-06	3E-06
P330	5E-04	8E-04	0.001	9E-05	1E-04	2E-04	0.002	0.002	0.003	0.001	0.002	0.002	3E-04	0.0005	8E-04	1E-03	0.002	0.002	4E-04	7E-04	9E-04	1E-06	2E-06	3E-06
P331	7E-04	0.001	0.001	1E-04	2E-04	2E-04	0.002	0.003	0.003	0.001	0.002	0.002	2E-04	0.0003	4E-04	0	0	0	3E-04	5E-04	7E-04	2E-05	3E-05	4E-05

P332	4E-04	6E-04	7E-04	3E-05	4E-05	6E-05	0.001	0.002	0.002	8E-04	0.001	0.002	2E-04	0.0003	4E-04	7E-04	0.001	0.001	5E-04	7E-04	9E-04	2E-06	3E-06	5E-06
P333	6E-04	9E-04	0.001	1E-05	2E-05	3E-05	0.003	0.004	0.005	0	0	0	0	0	0	0	0	0	6E-04	1E-03	0.001	3E-06	6E-06	8E-06
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
P768	3E-04	5E-04	7E-04	1E-05	2E-05	3E-05	0.001	0.002	0.003	0.001	0.002	0.002	3E-04	0.0005	7E-04	0	0	0	4E-04	7E-04	9E-04	4E-06	6E-06	9E-06
Weight	**0.37**	**0.57**	**0.73**	**0.50**	**0.67**	**0.80**	**0.30**	**0.50**	**0.67**	**0.50**	**0.70**	**0.83**	**0.27**	**0.43**	**0.60**	**0.50**	**0.70**	**0.83**	**0.37**	**0.57**	**0.77**	**0.30**	**0.50**	**0.70**

Table. 8. Shows calculate the separation measures and closeness coefficient to the ideal solution

Alternatives	Age	Pregnancies	Glucose	Blood Pressure	Skin Thickness	Insulin	BMI	Diabetes Pedigree Function	S+	S-	CCi	Rank
P1	0.0009	0.00034	0.00462	0.00156	0.001543	0.02237	0.00105	5E-05	0.03244	0.008	0.19782	663
…	…	…	…	…	…	…	…	…	…	…	…	…
P248	6E-05	0.00053	0.00515	0.001	0.001591	0.0121	0.00163	5.5E-05	0.02212	0.02936	0.57032	1
P249	0.0004	0.00025	0.00387	0.00162	0.001591	0.0135	0.0011	5.9E-05	0.0224	0.02163	0.49117	16
P250	6E-05	0.0005	0.00346	0.00112	0.001929	0.02237	0.00094	6.3E-05	0.03045	0.00987	0.24481	445
P251	0.0007	0.00025	0.00331	0.00218	0.002387	0.02237	0.00097	5.7E-05	0.03218	0.00813	0.20158	648
P252	0.0002	0.00047	0.00403	0.00119	0.002387	0.02237	0.00087	5.9E-05	0.03155	0.00881	0.21827	570
P253	9E-05	0.00047	0.00281	0.00131	0.002049	0.02093	0.00076	6E-05	0.02849	0.01208	0.29771	283
P254	0.0001	0.00053	0.00268	0.00169	0.001615	0.02237	0.00112	6.1E-05	0.03019	0.01009	0.25047	420
P255	0.0007	0.00016	0.00287	0.00187	0.002218	0.01612	0.00086	4.2E-05	0.02486	0.01723	0.40931	42
P256	0	0.0005	0.00353	0.00181	0.001543	0.02237	0.00105	5.2E-05	0.03085	0.00948	0.235	487
P257	0.0003	0.00044	0.00346	0.00206	0.001447	0.02237	0.00094	5.2E-05	0.03105	0.00927	0.22996	517
…	…	…	…	…	…	…	…	…	…	…	…	…
P324	0.0007	0.00012	0.00474	0.001	0.001591	0.02161	0.00084	4.7E-05	0.03063	0.00996		443
P325	0	0.00047	0.0035	0.00147	0.001615	0.02237	0.00111	6.3E-05	0.03059	0.00973		460
P326	9E-05	0.0005	0.0049	0.00156	0.001881	0.01814	0.0008	6.4E-05	0.02794	0.01356		162
P327	0.0003	0.0005	0.00381	0.00181	0.001615	0.01843	0.0011	4.8E-05	0.02758	0.01369		151
P328	0.0005	0.00022	0.00559	0.00162	0.002387	0.02237	0.0011	6.2E-05	0.03384	0.0068		734
P329	6E-05	0.00047	0.00318	0.00112	0.001519	0.0193	0.00142	6.4E-05	0.02714	0.01384		133
P330	0.0005	0.00034	0.00328	0.00162	0.001615	0.0206	0.00096	6.4E-05	0.02898	0.01168		333
P331	0.0008	0.00028	0.00368	0.00156	0.001929	0.02237	0.00072	2.6E-05	0.03135	0.00899		543
P332	0.0001	0.00047	0.00272	0.002	0.002001	0.02101	0.00102	6.3E-05	0.0294	0.01114		366
P333	0.0006	0.0005	0.00562	0.00381	0.002387	0.02237	0.00135	5.9E-05	0.03671	0.00393		768
…	…	…	…	…	…	…	…	…	…	…	…	…

P768	6E-05	0.0005	0.0029	0.00162	0.00164	0.02237	0.00095	5.8E-05	0.0301	0.01018	0.25277	409

5. Conclusion

Since diabetes mellitus has become widespread among humans is become a necessity to determine the symptoms that lead to this disease. Early diagnosis of these symptoms may help people with diabetes mellitus to reduce the likelihood of developing it. In this paper, a new framework for evaluating symptoms of diabetes is proposed. An innovative methodology was adopted in evaluating the various criteria based on the triangular fuzzy numbers approach. As well, the Fuzzy-TOPSIS method is applied to select the best and worst-case among the group of patients with this disease based on different criteria. This framework helps people identify the most important symptoms of diabetes and how to prevent it. The results show the best case at (P 248), and the worst-case at (P333) from the group of patients with diabetes mellitus. In future works, this framework could be applied with further symptoms or other diseases to help both people and physicians. Thus, we recommend to people should be monitoring these symptoms in their lives on a daily basis to prevent infection with this disease, and this is important to enjoy in good health.

Akenwlogment

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