How to Cite:
Lekshmi, I., & Regees, M. (2022). A review on fuzzy multi-criteria decision-making methods in medical diagnosis. *International Journal of Health Sciences*, *6*(S5), 2546–2554.
https://doi.org/10.53730/ijhs.v6nS5.9198

A review on fuzzy multi-criteria decision-making methods in medical diagnosis

Lekshmi I
Research Scholar, Registration No.-21113082092002
Email: lekshmiindira21@gmail.com

Regees M
Assistant Professor, Research Department of Mathematics, Malankara Catholic College, Mariagiri, Kaliyakkavilai- 629153, Tamilnadu, India (Affiliated to Manonmaniam Sudaranar University, Abishekapatti, Tirunelveli– 627012, Tamilnadu, India)
Email: regeesregees@gmail.com

***Abstract*---**In a real-world computing environment, the information is not complete, precise, and certain, making it very difficult to derive an actual decision. Uncertainty is a factor that makes the decision-making process more difficult in medical diagnosis. Everyone is different from the other at the physical level as well as mental level, symptoms of a disease expressed by patients are linguistic in nature and vary from person to person. That is why Decision making in medical diagnosis is becoming a vast research field in medical science. In medical diagnosis, generally, uncertainty (vagueness or imprecision) arises due to patients' vague linguistic expression of their problems to medical experts. The field of medicine and decision-making are the most fruitful and interesting areas of applications of fuzzy set theory. In the present paper, we study the importance of different fuzzy sets and fuzzy multi-criteria decision-making methods in the field of medical diagnosis. AMS Mathematics Classification: - 03B52, 03E72

***Keywords*---**Medical diagnosis, Fuzzy Matrix, Fuzzy Sets, Fuzzy Decision- Making methods.

1. Introduction

A major task of medical science is to diagnose diseases. Hence medical diagnosis is the art of determining a person's pathological conditions of the body, from all the available symptoms. In the medical field, dealing with diagnosis error and several levels of uncertainties and imprecision in the diagnoses of diseases had

Manuscript submitted: 18 Feb 2022, Manuscript revised: 27 April 2022, Accepted for publication: 9 June 2022

been a great challenge [13]. The representation of the uncertain and imprecise knowledge of medical documentation gives rise to a fuzzy environment.

The fuzzy set theory also plays a vital role in the field of Decision Making. There are varieties of models involving fuzzy matrices to deal with different complicated aspects of medical diagnosis. Sanchez formulated the diagnostic models involving fuzzy matrices representing the medical knowledge between symptoms and diseases [5, 6]. Esogbue and Elder [3] utilized fuzzy cluster analysis to model medical diagnostic. Meenakshi and Kaliraja [4] have extended Sanchez's approach for medical diagnosis using the representation of an interval-valued fuzzy matrix. They have also introduced the arithmetic mean matrix of an interval-valued fuzzy matrix and directly applied Sanchez's method of medical diagnosis to it. Baruah [7] used the definition of a complement of a fuzzy soft set proposed by Neog and Sut [11] and put forward a matrix representation of a fuzzy soft set and extended Sanchez's approach for medical diagnosis. Edward Samuel and Balamurugan [12] studied Sanchez's approach to medical diagnosis using an Intuitionistic fuzzy set. Multi-Criteria Decision-Making (MCDM)methods are a very powerful and useful tool for reliable decision-making in different fields of decision-making, especially in medical diagnosis. Among the contributions in the health care industry are in diagnosing certain diseases, comparing the efficiency of medical equipment, finding the best treatment technique for a particular disease, explanation of sets of medical discoveries and outcomes, and real-time observing of patient data [14]. There are several Fuzzy MCDM methods such as Fuzzy TOPSIS, AHP, PROMETHEE, etc, which are extensively used in medical diagnosis. In the present paper, we will study how different Fuzzy sets and Fuzzy MCDM methods have been applied in the medical field.

2. Preliminaries

Definition 2.1. (Triangular fuzzy number matrix) [2]
Triangular fuzz number matrix of order mxn is defined as A = $(a_{ij})_{mxn}$ where a_{ij}= $(a_{ijL}, a_{ijM}, a_{ijU})$ is the ij^{th}element of A. a_{ijL}, $a_{ijU}$are the left and right spreads of a_{ij}respectively and $a_{ijM}$is the mean value.

Definition 2.2. (Addition and subtraction operation on triangular fuzzy number matrix) [2]
Let A = $(a_{ij})_{nxn}$ and B =$(b_{ij})_{nxn}$be two triangular fuzzy number matrices of same order.
Then (i) Addition Operation
A (+) B = $(a_{ij} + b_{ij})_{nxn}$where
$(a_{ij}+ b_{ij})$= $(a_{ijL}+b_{ijL}, a_{ijM} +b_{ijM}, a_{ijU}+b_{ijU})$ is the ijth element of A(+)B
(ii) Subtraction Operation
A (-) B =$(a_{ij} - b_{ij})_{nxn}$ wherea_{ij} -b_{ij} = $(a_{ijL}$- $b_{ijU}, a_{ijM} - b_{ijM}$, a_{ijU}-$b_{ijL})$ is the ij^{th}element of A(-)B
The same condition holds for triangular fuzzy membership number too.

Definition 2.3 (Multiplication operation on triangular fuzzy number matrix) [2]
Let A= $(a_{ij})_{mxp}$ and B =$(b_{ij})_{pxn}$ be two triangular fuzzy number matrices. Then the

Multiplication Operation: A (.)B =$(c_{ij})_{mxn}$, where (c_{ij}) = $\sum_{k=1}^{p} a_{ik} b_{kj}$ for i = 1, 2 .....,m and j = 1,2,.....n.

Definition 2.4. (Max-min composition on fuzzy membership value matrices)
"Let F_{mn} denote the set of all mxn matrices over F. Elements of F_{mn} are called as fuzzy membership value matrices.
For A = (a_{ij}) ϵ F_{mxp} and B = (bij) ϵ F_{pxn} the max-min product A(.)B = (sup_k [{inf{a_{ik}; b_{kj}}}]) ϵ F_{mxn}."

Definition 2.5. (Maximum operation on triangular fuzzy number)
"Let A =$(a_{ij})_{nxn}$ where a_{ij} = (a_{ijL} , a_{ijM}, a_{ijU}) and B =$(b_{ij})_{nxn}$ where b_{ij}= (b_{ijL}, b_{ijM} , b_{ijU}) be two triangular fuzzy number matrices of same order. Then the maximum operation on it is
given by L_{max}= max(A, B) = (sup{ a_{ij} ; b_{ij}) where sup{a_{ij} , b_{ij} } = (sup(a_{ijL} ; b_{ijL}), sup(a_{ijM}; , b_{ijM}) , sup(a_{ijU}; b_{ijU})) is the ij^{th} element of max(A, B)."

Definition 2.6 (Arithmetic mean (AM) for triangular fuzzy number)
"Let A = (a_1, a_2 , a_3) be a triangular fuzzy number then AM (A) = $\frac{a_1+a_2+a_3}{3}$
The same condition holds for triangular fuzzy membership number."

Definition 2.7 (Type-1 Fuzzy Sets)
"A fuzzy set whose membership values are itself a fuzzy set."

Definition 2.8 (Type-2 Fuzzy Sets) [8]
A type 2 fuzzy set $\widehat{A}$ is a fuzzy set whose membership values are type 1 fuzzy sets on [0,1] and is expressed by the following set notation:
$\hat{A}$={$(x, \mu_{\hat{A}}(x)/x \in X$} where $\mu_{\hat{A}}$:X→F [0,1]

Definition 2.9 (Intuitionistic Fuzzy Sets) [30]
Let a set E be fixed. An intuitionistic fuzzy set or IFS A in E is an object having the form A={$(x, \mu_A(x), V_A(x))/x \in X$} where the functions μ_A : E → [0, 1] and V_A : E → [0, 1] define the degree of membership and degree of non-membership respectively of the element x ∈E to the set A, which is a subset of E, and for every x ∈E 0≤$\mu_A(x)$) +$V_A(x)$≤1.
The amount π_A(x) =1 − ($\mu_A(x)$ +$V_A(x)$) is called the hesitation part, which may cater to either membership value or non-membership value or both.

3. Medical Diagnosis Under Fuzzy Environment
3.1 An Application of Fuzzy Matrices in Medical Diagnosis [10]

Let S be the set of symptoms of certain diseases, D is a set of diseases and P is a set of patients. The elements of triangular fuzzy number matrix are defined as A = $(a_{ij})_{m\times n}$
where (a_{ij}) =(a_{ijL} , a_{ijM}, a_{ijU}) is the ij^{th} element of A, 0≤ a_{ijL} ≤a_{ijM} ≤ a_{ijU} ≤ 10. Here a_{ijL} is the lower bound, a_{ijM} is the moderate value and a_{ijU} is the upper bound.

Procedure 3.1.1

Step 1: Construct a triangular fuzzy number matrix (F, D) over S, where F is a mapping given by F: D → $\hat{F}$(S), $\hat{F}(S)$ is a set of all triangular fuzzy sets of S. This matrix is denoted by R_0which is the fuzzy occurrence matrix or symptom-disease triangular fuzzy number matrix.

Step 2: Construct another triangular fuzzy number matrix (F_1, S) over P, where $F_1$is a mapping given by F_1: S → F (P). This matrix is denoted by $R_s$which is the patient -symptom triangular fuzzy number matrix.

Step: Convert the elements of triangular fuzzy number matrix into its membership function as follows: Membership function of (a_{ij}) = $(a_{ijL}, a_{ijM}, a_{ijU})$ is defined as $\mu_{aij} = \left(\frac{a_{ijL}}{10}, \frac{a_{ijM}}{10}, \frac{a_{ijU}}{10}\right)$ if $0 \le a_{ijL} \le a_{ijM} \le a_{ijU} \le 10$

Where $0 \le \frac{a_{ijL}}{10} \le \frac{a_{ijM}}{10} \le \frac{a_{ij_U}}{10} \le 1$

Now the matrix R_0 and R_s are converted into triangular fuzzy membership matrices namely $(R_o)_{mem}$ and $(R_s)_{mem}$.

Step 4: compute the following relation matrices.

R_1= $(R_s)_{mem}$ (.) $(R_o)_{mem}$ it is calculated using Definition 2.4

R_2 = $(R_s)_{mem}$ (.) (J (-) $(R_0)_{mem}$), where J is the triangular fuzzy membership matrix in which all the entries are (1,1,1). (J(-) $(R_o)_{mem}$) is the complement of $(R_o)_{mem}$ and it is called as non -symptom -disease triangular fuzzy membership matrix.

R_3= (J(-)($(R_s)_{mem}$)(.)$(R_0)_{mem}$, where (J(-)(R_s)mem) is the complement of R_s and it is called as non patient-symptom triangular fuzzy membership matrix. R_2 and R_3 are calculated using subtraction operation and Definition 2.4

R_4= max{R_2;R_3 }. It is calculated using Definition 2.5

The elements of $R_{1,}$ R_2, R_3, R_4 is of the form y_{ij} = (y_{ijL},y_{ijM},y_{ijU})

where $0 \le y_{ijL} \le y_{ijM} \le y_{ijU} \le 1$.

R_5 = R_1 (-) R_4. It is calculated using subtraction operation. The elements of R_5 is of the form Z_{ij} = (Z_{ijL}, Z_{ijM}, Z_{ijU}) ∈ [-1,1] where $Z_{ijL} \le Z_{ijM} \le Z_{ijU}$.

Step 5: Calculate R_6 = AM (z_{ij}) and Row'$_i$= Maximum of i^{th} row which helps the decision maker to strongly confirm the disease for the patient.

3.2 Application of Type -2 Fuzzy Set Theory in Medical Diagnosis [8]

The theory of type-2 fuzzy sets is an intuitive and computationally feasible in addressing uncertain and imprecise information in decision making by extending the Sanchez's approach. The following was the proposed algorithm:

Step 1: Introduce type-2 fuzzy relation (type-2 fuzzy matrix), $\hat{A}$ to model the uncertainties of the state of the patient.

Step 2: Obtain the physician medical knowledge in the form of type-2 fuzzy relation $\hat{R}$ which shows the association between symptoms and diseases.

Step 3: Use an appropriate compositional rule to infer the association between patients and diseases.

Step 4: An appropriate defuzzification method is used to make diagnostic decision.

3.3 Application of Intuitionistic Fuzzy Sets in Medical Diagnosis [1, 9]

Intuitionistic fuzzy sets as a generalization of fuzzy sets can be useful in situations when description of a problem by a (fuzzy) linguistic variable, given in terms of a membership function only, seems too rough. For example, in decision making problems, particularly in the case of medical diagnosis there is a fair chance of the existence of a non-null hesitation part at each moment of evaluation of an unknown object. To be more precise - intuitionistic fuzzy sets let us express for e.g., the fact that the temperature of a patient changes, and other symptoms are not quite clear, Intuitionistic fuzzy sets can be used as a tool for reasoning in the presence of imperfect facts and imprecise knowledge.

Analogous to Sanchez's notion of "Medical Knowledge" "Intuitionistic Medical Knowledge" as an intuitionistic fuzzy relation R from the set of symptoms S to the set of diagnoses D (i.e., on S × D) had been defined which reveals the degree of association and the degree of non-association between symptoms and diagnosis.
The methodology involves mainly the following three jobs: 1. Determination of symptoms. 2. Formulation of medical knowledge based on intuitionistic fuzzy relations. 3. Determination of diagnosis on the basis of composition of intuitionistic fuzzy relations. Let A be an IFS of the set S; and R be an IFR from S. Let A be an IFS of the set S; and R be an IFR from S to D. Then max–min–max composition [14] B of IFS A with the IFR R(S → D) denoted by B = A∘R signifies the state of the patient in terms of diagnosis as an IFS B of D with the membership function given by
μ_B(d)=$\underset{s\in S}{\cup}[\mu_A(s)\cap\ \mu_R(s,\ d)]$ and the non-membership function is given by
V_B(d)=$\underset{s\in S}{\cap}[V_A(s)\cap\ V_R(s,\ d)]$ for all d∈D ($\cup= max$,$\cap= min$)
If the state of a given patient P is described in terms of an IFS A of S; then P is assumed to be assigned diagnosis in terms of IFS B of D, through an IFR R of "Intuitionistic Medical Knowledge" from S to D which is assumed to be given by a doctor who is able to translate his own perception of the intuitionism involved in degrees of association and non-association respectively between symptoms and diagnosis.

3.4 Application of Fuzzy Soft Sets in Medical Diagnosis [11, 12]

A matrix representation of fuzzy soft set had been introduced and extended by Sanchez known as Sanchez's approach for medical diagnosis using the notion of fuzzy soft complement. The proposed algorithm was as follows:-
Algorithm:-
1. Input the fuzzy soft set (F, D) and compute $(F,D)^c$.Compute the corresponding matrices $R_1$and R_2
2. Input the fuzzy soft set (F_1, S) and compute $(F_1,S)^c$. Compute the corresponding matrices Q_1 and Q_2
3. Compute $T_1 = Q_1 - R_1, T_2 = Q_1 - R_2, T_3 = Q_2 - R_1, T_4 = Q_2 - R_2$
4. Compute the corresponding membership value matrices MV(T_1),MV(T_2), MV(T_3),MV(T_4)
5. Compute the diagnosis scores ST_1, ST_2 etc.
6. Find S_k=$^{max}_{\ j}(S_{T_1}(p_i,d_j) - S_{T_2}(p_i,d_j))$ We conclude that the patient $p_i$is suffering from the disease d_k.
7. If $S_k$has more than one value, then go to step (1) and repeat the process by

reassessing the symptoms for the patient.

4 Decision Making Methods In Medical Diagnosis

This study mainly focuses on some of the application of decision- making methods such as Fuzzy TOPSIS, AHP, PROMETHEE etc. in medical diagnosis.

4.1 TOPSIS Method

In 2020 Khalid Naeem proposed a mathematical analysis of viral hepatitis types using Pythagorean fuzzy soft sets (PFSSs) via TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), VIKOR (Vise Kriterijumska Optimizacija Kompromisno Resenje) and generalized aggregation operator models and showed that both the techniques render the same optimal choice [15]. Later Naime Demirtas calculated an artificial neural network related to the consistency of convergence coefficients by the Fuzzy TOPSIS method and understood the accuracy of the results.[16].Aswini Kodipalli conducted a study based on Fuzzy TOPSIS method to detect and diagnose the likelihood of having PCOS and its associated mental health problems. Since the clinical and psychological data pertaining to PCOS varies from woman to woman and involves inherent uncertainty, imprecision, and ambiguity, the traditional machine learning algorithms will not model the system under consideration.[17] Priyanka Majumder and Piyali Biswas introduced a new TOPSIS approach named TOPSIS - 1 to identify the most significant risk factor and continuous monitoring of death of covid-19 where they had computed the separation measures, using the m dimensional supremum distance instead of Euclidean distance[18]. Intuitionistic fuzzy TOPSIS method was proposed by Kiran Pal, V. Kumar and H. D. Arora for decision making by utilizing entropy weight to diagonise vector borne diseases such as chikungunya, dengue, and malaria etc [19].Apart from diagnosis Fuzzy TOPSIS method had been applied in selecting medical imaging devices as it was a challenging problem for both budget planning and medical decision making. Ismail Burak Parlak proposed a new methodology for the selection of medical devices using interval type-2 fuzzy sets combined with Wu and Mendel's centroid ranking method.[20]. Rana Muhammad Zulqarnain1developed a model for TOPSIS to select better hospitals or medical clinics in a country.[21].

4.2 Analytic Hierarchy Process [AHP]

AHP is a method for making alternative decision sequences and selecting the best alternative when decision makers with multiple objectives or criteria to make certain decisions. Gülçin Büyüközkan in a study combined Fuzzy AHP and TOPSIS to do the strategic analysis of electronic service quality in health care industry where the author had used AHP to compute the criteria weights and continued with Fuzzy TOPSIS methodology [22]. Muhammad Muslihudin had analyzed layer chicken disease using Fuzzy AHP. Diagnosis of poultry disease with certainty factor method that attacks poultry (chicken) was very helpful to the poultry farmers in anticipating the symptoms of treatment for a fast, precise and efficient [23] Farnaz Sabahi proposed a new FAHP, bimodal fuzzy analytic hierarchy process (BFAHP) that augmented two aspects of knowledge, probability and validity, to fuzzy numbers to better deal with uncertainty. In BFAHP, fuzzy validity was computed by aggregating the validities of relevant risk factors based on expert knowledge and collective intelligence. By considering both soft and statistical data, compute the fuzzy probability of risk factors using the Bayesian formulation. In BFAHP approach, these fuzzy validities and fuzzy probabilities were used to construct a reciprocal comparison matrix. Then aggregate fuzzy probabilities and fuzzy validities in a pairwise manner for each risk factor and each alternative. BFAHP decides about being affected and not being affected by ranking of high and low risks. For evaluation, the proposed approach had applied to the risk of being affected by coronary heart disease using a real data set of 152 patients of Iranian hospitals.[24]. Arati Mohapatro had put forward a decision support system (DSS) which would come to the aid of detection of Dengue fever by carrying out an analysis of AHP and fuzzy AHP (FAHP) methodology. The data of confirmed Dengue as diagnosed by a physician was picked up, examined independently using AHP and FAHP approach, and the results obtained were then compared with the diagnosis report of an expert doctor. The outcome indicated that expert systems could be leveraged for the diagnosis of Dengue and could be a useful tool for non-expert physicians.[25]. Phi-Hung Nguyenin in a study to provide an innovative new approach employing quantitative and qualitative techniques to understand individuals' vaccination intention during the global pandemic of COVID -19 proposed a novel three-staged approach combining Spherical Fuzzy Analytic Hierarchy Process (SF-AHP), Partial Least Squares-Structural Equation Model (PLS-SEM), and Artificial Neural Network (ANN)[26]. Fuzzy Analytic Hierarchy process had been used to prioritize factors of breast cancer treatment alternatives [Hatice Camgöz-Akdağ] [27]

4.3 Fuzzy PROMETHEE Method

Fuzzy PROMETHEE (Preference Ranking Organization Method for Enrichment of Evaluations), a multi-criteria decision-making process was used by Dilber Uzun Ozsahin to evaluate breast cancer treatment techniques on factors that include side effects, overall survival rate, cost of treatment and treatment time [28]. The author had employed Fuzzy PROMETHEE method in order to solve the decision making problems in nuclear imaging. In another study by Mordecai Maisaini this method was used to analyze the therapeutic techniques based on factors such as radiation dose, cost of treatment, treatment time, chances of survival, side effects and cost of the method for the hospital. Evaluation results showed that the surgery among other techniques showed a great performance on lung cancer treatment based on the criteria, importance, and weight they had selected. Fuzzy PROMETHEE also shows that one can easily modify the method by adding more criteria and change their importance and weights depending on the specific application. Recently, Fuzzy PROMETHEE technique was used to develop a new path for cancer treatment based on nanoparticles (NPs) applications, used in controlled anticancer drug delivery (drug release, toxicity, and unspecific site targeting) to enhance patient safety [29].

5. Conclusion

This paper provides several applications of fuzzy decision- making methods in medical diagnosis. Based on this study, future developments of fuzzy decision -making in medicine and healthcare can be forecast. As such, it appears to be eminently suited to aspects of medical decision making. Furthermore the principles behind fuzzy decision making are straightforward and is relatively easy.

References

[1] A. Edward Samuel and M. Balamurugan, Application of intuitionistic fuzzy sets in medical diagnosis, Proceeding of the International Conference on Mathematical Modelling and Applied Soft Computing 1 (2012), 189 -194.

[2] A.K.Shyamal and M.Pal, Triangular fuzzy matrices, Iranian Journal of Fuzzy Systems, 4(1) (2007) 75-87.

[3] A.O. Esogbue and R.C. Elder, Fuzzy Diagnosis decision models, Fuzzy sets and systems, 3 (1980), 1 - 9.

[4] A.R.Meenakshi and M.Kaliraja, An application of interval valued fuzzy matrices in medical diagnosis, International Journal of Mathematical Analysis, 5(36) (2011) 1791 - 1802.

[5] E.Sanchez, Inverse of fuzzy relations, application to possibility distribution and medical diagnosis, Fuzzy Sets and Systems, 2(1) (1979) 75 - 86.

[6] E. Sanchez, Resolution of composite fuzzy relation equations, Information and control, 30 (1976), 38 - 48.

[7] H.K. Baruah, The theory of fuzzy sets: Beliefs and Realities, International Journal of Energy, Information and Communication, 2(2) (2011), 1 - 22.

[8] Kamesh Kumar, Type-2 Fuzzy Set Theory in Medical Diagnosis, Annals of Pure and Applied Mathematics, Vol. 9, No. 1, 2015

[9] R. Biswas, Intuitionistic fuzzy relations, Bull. Sous. Ens. Flous. Appl. (BUSEFAL) 70 (1997) 22–29.

[10] R.Sophia Porchelvi, P.Selvavathi and R.Vanitha, An Application of Fuzzy Matrices in Medical Diagnosis,International Journal of Fuzzy Mathematical Archive, Vol. 9, No. 2, 2015, 211-216.

[11] Tridiv Jyoti Neog ,An Application of Fuzzy Soft Sets in Medical Diagnosis using Fuzzy Soft Complement, , International Journal of Computer Applications (0975 – 8887), Volume 33– No.9, November 2011

[12] T.J. Neog and D.K. Sut, Theory of fuzzy soft sets from a new perspective, International Journal of Latest Trends in Computing, 2(3) (2011), 439 -450.

[13] Labiga Laban Thomas1, Ibrahim Goni2, Gideon Daniel Emeje1, Fuzzy Models Applied to Medical Diagnosis: A Systematic Review, Advances in Networks 2019; 7(2): 45-50

[14] J.Greeda *1, A. Mageswari*2, R. Nithya*3, A Study On Fuzzy Logic And Its Applications In Medicine, International Journal of Pure and Applied Mathematics Volume 119 No. 16 2018, 1515-1525.

[15] Khalid Naeem1 · Muhammad Riaz2 · Faruk Karaaslan3, A mathematical approach to medical diagnosis via Pythagorean fuzzy soft TOPSIS, VIKOR and generalized aggregation operators, Complex & Intelligent Systems (2021) 7:2783–2795.

[16] Naime Dem˙irtas , Orhan Dalkilic¸ Consistency Measurement Using The Artificial Neural Network Of The Results Obtained With Fuzzy Topsis Method For The Diagnosis Of Prostate Cancer, TWMS J. App. and Eng. Math. V.11, N.1, 2021,

[17] Ashwini Kodipalli ,and Susheela Devi ,Prediction of PCOS and Mental health using Fuzzy inference and SVM.

[18] Priyanka Majumder 1 , Piyali Biswas 2 , Srestha Majumder 3, Application of New TOPSIS Approach to Identify the Most Significant Risk Factor and Continuous Monitoring of Death of COVID-19, Electronic Journal of General Medicine 2020, 17(6), em234.
[19] Kiran Pal, V. Kumar, H. D. Arora, Surendra Kumar, Application of TOPSIS in the Diagnosis of Vector Borne Diseases, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-8 Issue-6, August 2019.
[20] Ismail Burak Parlak, Evaluation Of Medical Devices Using Fuzzy Topsis With Type-2 Fuzzy Numbers,August 2014.
[21] Rana Muhammad Zulqarnain, Sohaib Abdal , Selection of Medical Clinic for Disease Diagnosis by Using TOPSIS Method, International Journal of Pharmaceutical Sciences Review and Research · March 2020.
[22] Gülçin Büyüközkan , Gizem Çifçi, A combined fuzzy AHP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare industry, Expert Systems with Applications,Elsevier 2012.
[23] Muhammad Muslihudin1 , Risma Wanti1 , Hardono2 , Prediction of Layer Chicken Disease using Fuzzy Analytical Hierarcy Process, International Journal of Engineering & Technology, 7 (2.26) (2018) 90-94.
[24] Farnaz Sabahi, Bimodal fuzzy analytic hierarchy process (BFAHP) for coronary heart disease risk assessment, Journal of Biomedical Informatics,2018.
[25] Arati Mohapatro, Clinical Decision Support System for Detection of Dengue: A Case Comparison Using AHP and Fuzzy AHP, Journal of Cases on Information Technology Volume 23 • Issue 4.
[26] Phi-Hung Nguyen, A Hybrid Model with Spherical Fuzzy-AHP, PLS-SEM and ANN to Predict Vaccination Intention against COVID-19, E-Mathematics, MDPI, November 2021.
[27] Hatice Camgöz-Akdağ, Aziz Kemal Konyalıoğlu, Tuğçe Beldek, Prioritization of Factors of Breast Cancer Treatment Using Fuzzy AHP, September2019.
[28] Dilber Uzun Ozsahin and Ilker Ozsahin, A Fuzzy PROMETHEE Approach for Breast Cancer Treatment Technique, International Journal of Medical Research & Health Sciences, 2018, 7(5): 29-32.
[29] Safa Anmar Albarwary , Ayse Gunay Kibarer, The Efficiency of AuNPs in Cancer Cell Targeting Compared to Other Nanomedicine Technologies Using Fuzzy PROMETHEE, Hindawi Journal of Healthcare Engineering Volume 2021, Article ID 1566834.
[30] Eulalia Szmidt and Janusz Kacprzyk, Intuitionistic Fuzzy Sets in Some MedicalApplications, Fifth Int. Conf. on IFSs, So ̄a, 22-23 Sept. 2001NIFS.
[31] Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2021). Health and treatment of diabetes mellitus. *International Journal of Health Sciences*, *5*(1), i-v. https://doi.org/10.53730/ijhs.v5n1.2864
[32] Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2021). The COVID-19 pandemic. *International Journal of Health Sciences*, *5*(2), vi-ix. https://doi.org/10.53730/ijhs.v5n2.2937
[33] Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2022). Post-pandemic health and its sustainability: Educational situation. *International Journal of Health Sciences*, *6*(1), i-v. https://doi.org/10.53730/ijhs.v6n1.5949