



Neutrosophic Multi-criteria Decision-making Methodology for Evaluation chronic obstructive pulmonary disease

Neyda Hernández Bandera^{1,*}, Jenny Maribel M. Arizaga², Enrique Rodríguez Reyes³

¹Docente de la carrera de Medicina de la Universidad Regional Autónoma de los Andes (UNIANDES), Ecuador

²Docente de la carrera de Medicina de la Universidad Regional Autónoma de los Andes (UNIANDES Santo Domingo), Ecuador

³Docente de la carrera de Medicina de la Universidad Regional Autónoma de los Andes (UNIANDES Ambato), Ecuador

Emails: ua.neydahernandez@uniandes.edu.ec; docentetp54@uniandes.edu.ec;
ua.enriquerodriguez@uniandes.edu.ec

Abstract

Chronic obstructive pulmonary disease (COPD), is a debilitating lung condition that may lead to several other serious health problems and even death if left untreated. The ability to diagnose illnesses quickly and affordably is crucial. First and foremost, helping physicians determine how severe COPD cases are is crucial for placing patients in the appropriate institutions. Based on system engineering principles and real-world clinical practice, this article develops a COPD severity evaluation indicator system followed by suggests a neutrosophic distance from the average solution (EDAS) approach to making decisions in a linguistically uncertain setting. The alternatives are ranked by how far they are from the average answer on every factor using the EDAS technique. Distance-based multi-criteria decision-making techniques are analogous to this approach. It expedites the decision-making process by streamlining the computation of distances to an agreed solution. The EDAS method is used to compute the weights of criteria and then rank the alternatives under the neutrosophic model. The neutrosophic set is used in this paper to solve the uncertain information in the process of this evaluation. The EDAS method is applied in various criteria and alternatives and the results are discussed.

Keywords: Neutrosophic Set; MCDM; EDAS; Evaluation Process; Pulmonary Disease

1. Introduction

COPD is the fourth biggest cause of death globally and is characterized by a gradual, steady decline in lung function due to permanent swelling in the airways. The rising mortality rate from COPD is posing an urgent threat to the healthcare system because of the lack of adequate early detection. Delivering effective therapy and lowering the cost of personalized care requires prompt and precise illness detection. Instead of relying on intelligent technologies, the existing system of illness identification and treatment planning relies on invasive disease diagnostic techniques and the expertise of the healthcare professional[1], [2].

In light of these significant obstacles, researchers are always on the lookout for new and improved methods of early illness identification that will ultimately benefit patients[3], [4]. The results show that volatile organic compounds (VOCs) in exhaled breath may be analyzed in a non-invasive way and show promise as indicators in the early identification of illness. Endogenous VOCs are produced by lipid peroxidation or pathophysiological processes or microorganisms in the liver, kidneys, and lungs, whereas external VOCs may originate from a variety of different sources[5]–[7].

Both the assessment procedure and the evaluation indicator system make up what is known as the medical evaluation system. The level of severity of a patient's COPD may be evaluated using an evaluation indicator system based on several classic symptoms and associated risks[8], [9]. While a group of doctors established several diagnostic requirements and treatment techniques, the process of evaluation is still lacking. This is due to a lack of both an evaluation model that corresponds to the doctors' conveying habits and an approach for making decisions that take into account a wide range of variables[10]–[12].

Smarandache extended intuitionistic fuzzy sets with his kind of logic called neutrosophic sets (NSs)[13]–[15]. The NS is characterized as the setting in which all cosmological elements have truth, indeterminacy, and falsity values inside the nonstandard unit interval $[0,1+]$. While levels of belongingness and non-belongingness and indeterminacy value were factored in as relativity or absoluteness, in the neutrosophic sets, ambiguity is expressed as truth and falsity numbers[16]–[18]. Neutrosophic sets use this notation to do more than only dealing with the system's uncertainty; it also helps people make better decisions when faced with contradictory data. As a result, the degrees of membership and non-membership correspond to the truth and falsehood values, respectively, while the degree of indeterminacy corresponds to the hesitant value[19]–[21].

The EDAS technique, developed by Keshavarz Ghorabae et al., evaluates solutions based on their distance from the average response[22]–[24]. So far, this strategy has been used to address issues in a wide range of contexts[25], [26].

The purpose of this study, evaluate COPD using the decision system. This system includes the neutrosophic and MCDM method. The neutrosophic set is used to overcome uncertain information. Then the neutrosophic hybrid with the EDAS method to evaluate COPD. The EDAS method is used with NS to compute the weights of criteria, then rank the alternatives.

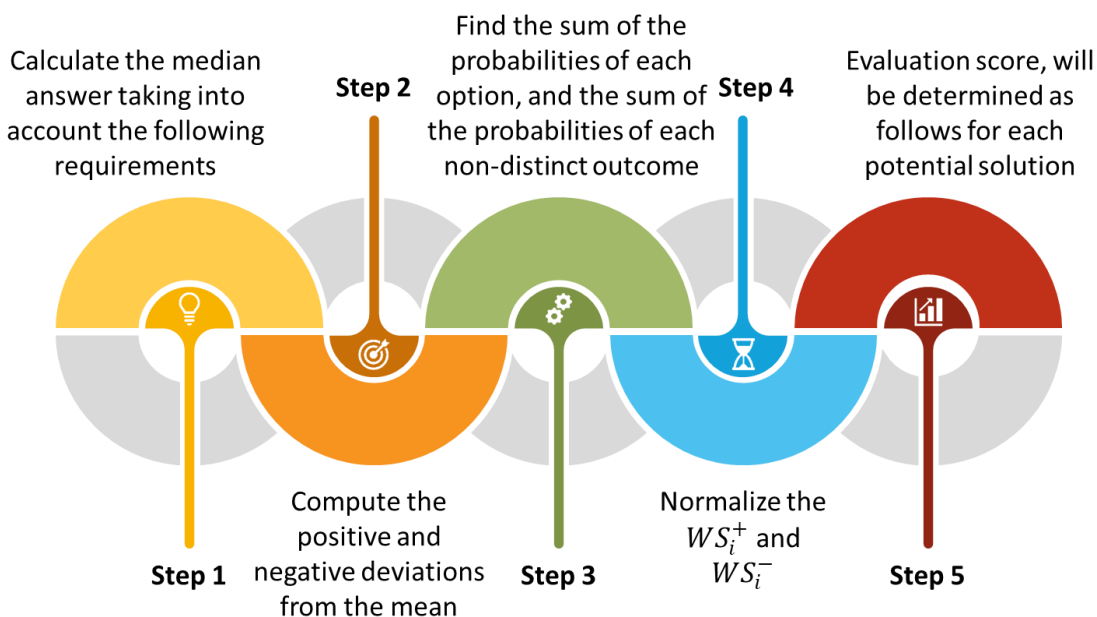


Figure 1: The steps of the EDAS method.

2. Methodology

The EDAS approach may be summarized as follows for addressing a decision-making issue with m potential solutions and n evaluation criteria[27]: The steps of the neutrosophic EDAS method are shown in Figure 1.

Step 1: Calculate the median answer taking into account the following requirements[28], [29]:

$$y_j = (y_1, y_2, y_3 \dots \dots y_n) \quad (1)$$

$$y_j = \frac{\sum_{i=1}^m y_{ij}}{m} \quad (2)$$

Where y_{ij} refers to the value of criteria with alternative

Step 2: Compute the positive and negative deviations from the mean in the manner of:

$$t_{ij}^+ = \begin{cases} \frac{\max(0, (y_{ij} - y_j))}{y_{ij}}; & j \in \max \\ \frac{\max(0, (y_j - y_{ij}))}{y_{ij}}; & j \in \min \end{cases} \quad (3)$$

$$t_{ij}^- = \begin{cases} \frac{\max(0, (y_j - y_{ij}))}{y_{ij}}; & j \in \max \\ \frac{\max(0, (y_{ij} - y_j))}{y_{ij}}; & j \in \min \end{cases} \quad (4)$$

Where max and min refer to the positive and negative criteria

Step 3: Find the sum of the probabilities of each option, and the sum of the probabilities of each non-distinct outcome:

$$WS_i^+ = \sum_{j=1}^n w_j t_{ij}^+ \quad (5)$$

$$WS_i^- = \sum_{j=1}^n w_j t_{ij}^- \quad (6)$$

Step 4: Normalize the WS_i^+ and WS_i^-

$$N_i^+ = \frac{WS_i^+}{\max_k WS_k^+} \quad (7)$$

$$N_i^- = 1 - \frac{WS_i^-}{\max_k WS_k^-} \quad (8)$$

Step 5: The evaluation score, will be determined as follows for each potential solution:

$$N_i = 0.5(N_i^+ + N_i^-) \quad (9)$$

Then rank the alternatives according to the highest value of N_i [30],[31].

3. Results

This section presented the results of applying the steps of the neutrosophic EDAS method. Also, this section presented a case study with ten different patients with the same doctor with eight criteria[1], [2]. The eight criteria are listed in Figure 2.

First, build the decision matrix between criteria and alternatives for the doctors. Table 1 shows the decision matrix.

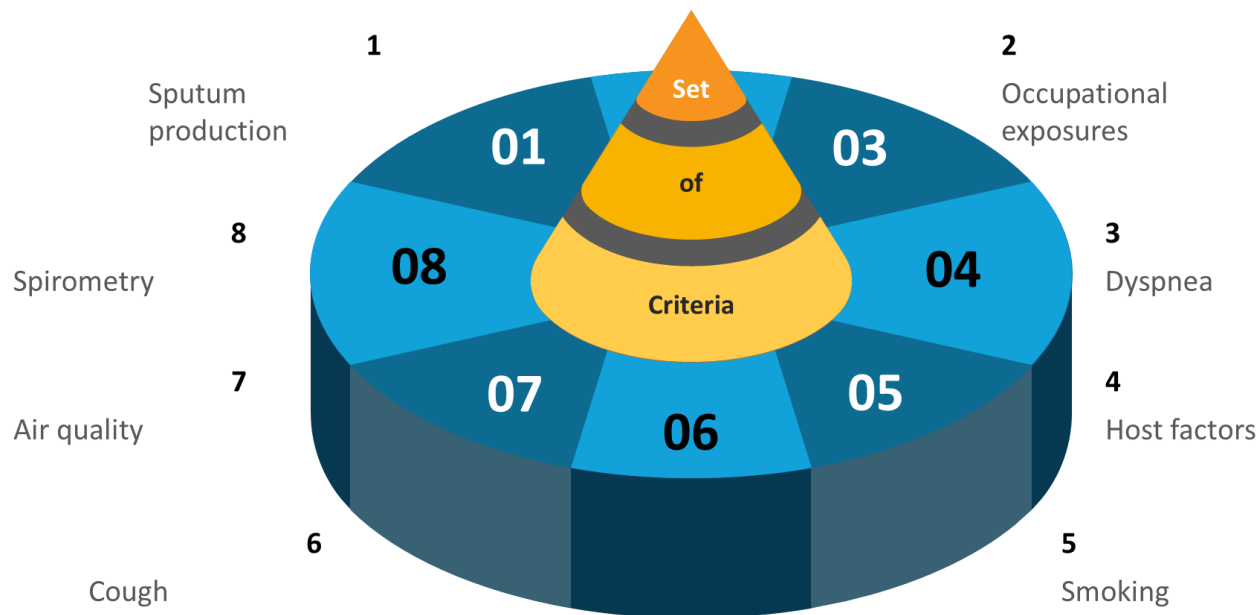


Figure 2: The list of eight criteria.

Table 1: The decision matrix by the doctors.

	PDC ₁	PDC ₂	PDC ₃	PDC ₄	PDC ₅	PDC ₆	PDC ₇	PDC ₈
PDA ₁	<0.9,1.0,1.0>	<0.9,0.2,0.3>	<0.8,0.3,0.4>	<0.6,0.4,0.5>	<0.4,0.5,0.6>	<0.4,0.5,0.6>	<0.2,0.7,0.8>	<0.3,0.6,0.7>
PDA ₂	<0.8,0.3,0.4>	<0.8,0.3,0.4>	<0.9,0.2,0.3>	<0.9,1.0,1.0>	<0.2,0.7,0.8>	<0.2,0.7,0.8>	<0.3,0.6,0.7>	<0.3,0.6,0.7>
PDA ₃	<0.9,0.2,0.3>	<1.0,0.0,0.0>	<1.0,0.0,0.0>	<0.9,0.2,0.3>	<0.9,1.0,1.0>	<0.9,1.0,1.0>	<0.8,0.3,0.4>	<0.3,0.6,0.7>
PDA ₄	<0.8,0.3,0.4>	<0.9,1.0,1.0>	<0.9,0.2,0.3>	<0.9,1.0,1.0>	<1.0,0.0,0.0>	<0.4,0.5,0.6>	<0.9,0.2,0.3>	<0.4,0.5,0.6>
PDA ₅	<0.3,0.6,0.7>	<0.9,0.2,0.3>	<0.9,1.0,1.0>	<0.9,0.2,0.3>	<0.3,0.6,0.7>	<1.0,0.0,0.0>	<0.9,0.2,0.3>	<0.2,0.7,0.8>
PDA ₆	<0.2,0.7,0.8>	<0.8,0.3,0.4>	<0.9,0.2,0.3>	<0.8,0.3,0.4>	<0.3,0.6,0.7>	<0.9,1.0,1.0>	<0.8,0.3,0.4>	<0.8,0.3,0.4>
PDA ₇	<0.4,0.5,0.6>	<0.9,0.2,0.3>	<0.2,0.7,0.8>	<0.9,0.2,0.3>	<0.2,0.7,0.8>	<0.8,0.3,0.4>	<0.9,0.2,0.3>	<0.9,0.2,0.3>
PDA ₈	<0.4,0.5,0.6>	<0.8,0.3,0.4>	<0.4,0.5,0.6>	<0.6,0.4,0.5>	<0.4,0.5,0.6>	<0.9,0.2,0.3>	<0.9,0.2,0.3>	<0.9,1.0,1.0>
PDA ₉	<0.3,0.6,0.7>	<0.9,0.2,0.3>	<0.8,0.3,0.4>	<0.4,0.5,0.6>	<0.3,0.6,0.7>	<0.4,0.5,0.6>	<0.8,0.3,0.4>	<0.9,1.0,1.0>
PDA ₁₀	<0.3,0.6,0.7>	<0.2,0.7,0.8>	<0.2,0.7,0.8>	<0.4,0.5,0.6>	<0.4,0.5,0.6>	<0.8,0.3,0.4>	<0.9,0.2,0.3>	<0.9,1.0,1.0>

Then compute the weights of criteria by the EDAS method. The weights of eight criteria are shown in Figure 3.

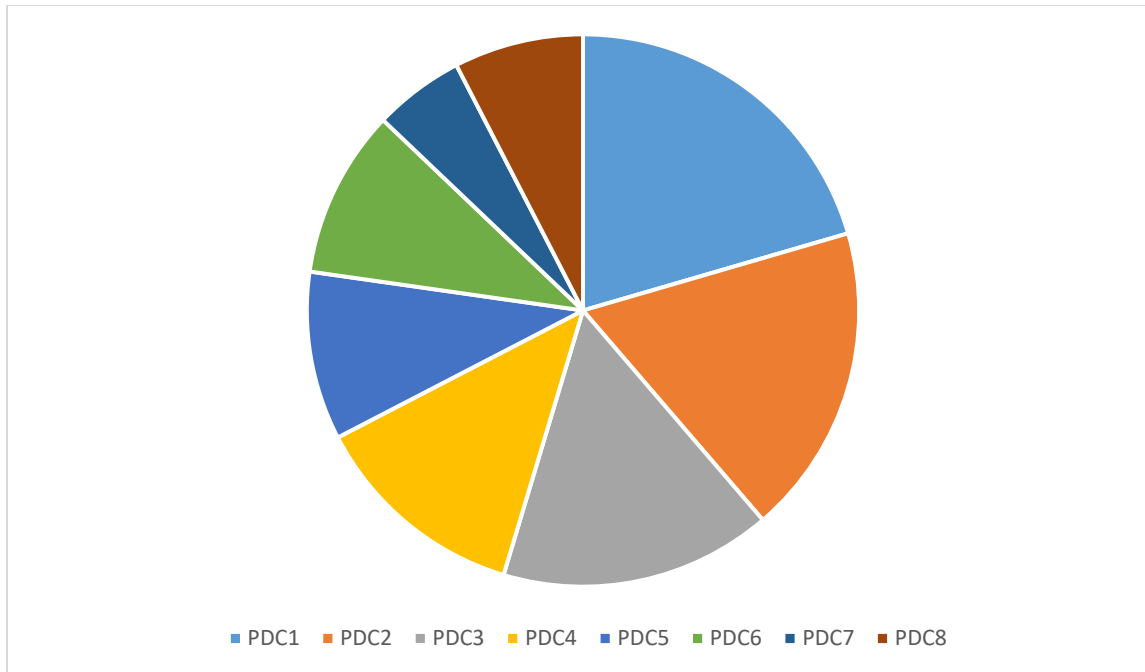


Figure 3: The weights of eight criteria.

Then compute the positive and negative deviations by using Eqs. (3 and 4). The positive and negative criteria are defined first. Then compute the sum of probabilities of each option, and the sum of the probabilities of each non-distinct outcome by using Eqs. (5 and 6). Then normalize the WS_i^+ and WS_i^- by using Eqs. (7 and 8). Table 2 shows the normalized values of WS_i^+ and WS_i^- . Then compute the evaluation score by using Eq. (9). Then rank the alternatives according to the largest value of the valuation score. Figure 4 shows the rank of alternatives.

Table 2: The normalized values of WS_i^+ and WS_i^- .

	PDC ₁	PDC ₂	PDC ₃	PDC ₄	PDC ₅	PDC ₆	PDC ₇	PDC ₈
PDA ₁	0	0.013895	0.009685	0	0	0	0	0
PDA ₂	0	0	0.033837	0.039144	0	0	0	0
PDA ₃	0	0.062906	0.082142	0.020627	0.091655	0.03725	0.002683	0
PDA ₄	0	0.0384	0.033837	0.039144	0.112793	0	0.010645	0
PDA ₅	0.073649	0.013895	0.05799	0.020627	0	0.052343	0.010645	0
PDA ₆	0.113069	0	0.033837	0.002111	0	0.03725	0.002683	0.014673
PDA ₇	0.03411	0.013895	0	0.020627	0	0.007064	0.010645	0.0276
PDA ₈	0.034229	0	0	0	0	0.022157	0.010645	0.040528
PDA ₉	0.073649	0.013895	0.009685	0	0	0	0.002683	0.040528
PDA ₁₀	0.073649	0	0	0	0	0.007064	0.010645	0.040528
	PDC ₁	PDC ₂	PDC ₃	PDC ₄	PDC ₅	PDC ₆	PDC ₇	PDC ₈
PDA ₁	0.149864	0	0	0.023812	0.00706	0.033235	0.034499	0.032771
PDA ₂	0.071023	0.010611	0	0	0.049336	0.063421	0.026776	0.032771
PDA ₃	0.110444	0	0	0	0	0	0	0.032771
PDA ₄	0.071023	0	0	0	0	0.033235	0	0.019844
PDA ₅	0	0	0	0	0.028198	0	0	0.045699
PDA ₆	0	0.010611	0	0	0.028198	0	0	0
PDA ₇	0	0	0.103106	0	0.049336	0	0	0
PDA ₈	0	0.010611	0.054801	0.023812	0.00706	0	0	0

PDA ₉	0	0	0	0.047328	0.028198	0.033235	0	0
PDA ₁₀	0	0.125052	0.103106	0.047328	0.00706	0	0	0

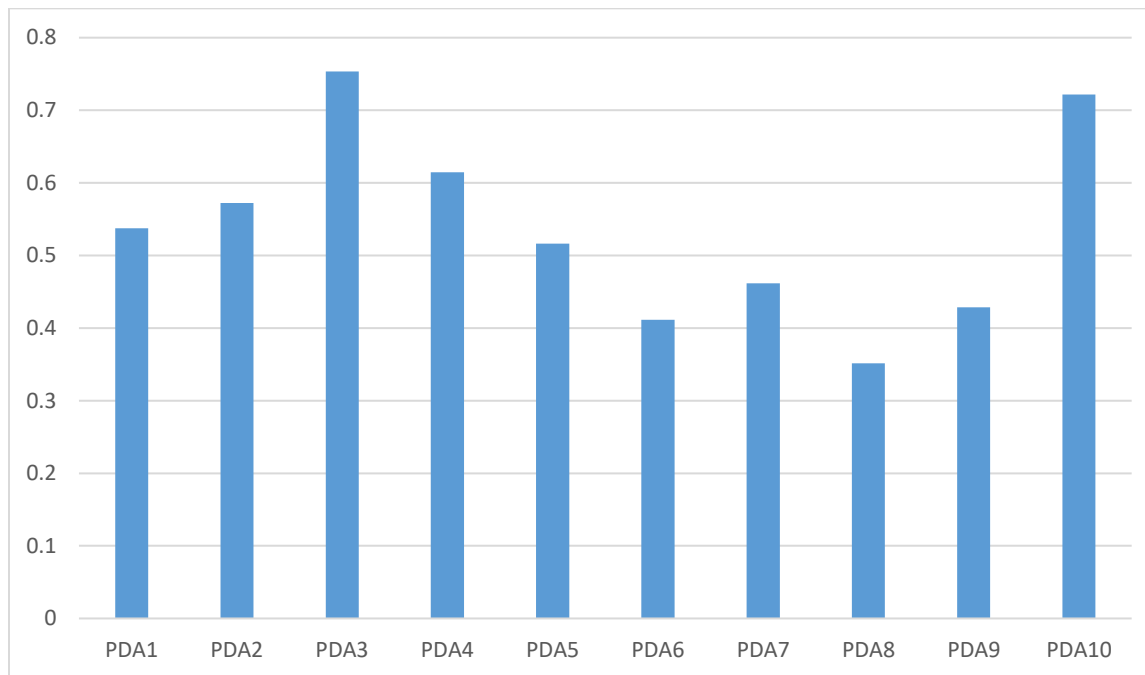


Figure 4: The rank disease of patients.

4. Conclusion

Patients choose general hospitals to competent, entry-level medical facilities for the treatment of their illnesses, regardless of whether their conditions are acute, stable, severe, or moderate. COPD is one of the most prevalent illnesses, and its two possible medical outcomes need distinct approaches to therapy. As a result, it is important to determine the COPD severity before sending patients to other hospitals. In this paper, we suggest an expansion of the EDAS approach that makes use of single-valued neutrosophic numbers. Objective happiness and discontent may both be expressed using single-valued neutrosophic quantities since they allow for the application of truth- and falsity-membership operations. Decision-makers may also communicate their certainty about predetermined levels of pleasure and discontent by using the indeterminacy-membership function. When compared to other evaluation methods, the standard EDAS approach is quite straightforward to grasp. The major goal of this work was to provide a modification of the EDAS approach that was intuitive and simple to implement.

References

- [1] Y. Zheng, Z. Xu, Y. He, and H. Liao, "Severity assessment of chronic obstructive pulmonary disease based on hesitant fuzzy linguistic COPRAS method," *Appl. Soft Comput.*, vol. 69, pp. 60–71, 2018.
- [2] G. S. Karthick and P. B. Pankajavalli, "Chronic obstructive pulmonary disease prediction using Internet of things-spiro system and fuzzy-based quantum neural network classifier," *Theor. Comput. Sci.*, vol. 941, pp. 55–76, 2023.
- [3] S. Zeng, M. Arjomandi, Y. Tong, Z. C. Liao, and G. Luo, "Developing a machine learning model to predict severe chronic obstructive pulmonary disease exacerbations: retrospective cohort study," *J. Med. Internet*

- Res., vol. 24, no. 1, p. e28953, 2022.
- [4] A. Westcott, D. P. I. Capaldi, D. G. McCormack, A. D. Ward, A. Fenster, and G. Parraga, "Chronic obstructive pulmonary disease: thoracic CT texture analysis and machine learning to predict pulmonary ventilation," *Radiology*, vol. 293, no. 3, pp. 676–684, 2019.
- [5] G. Altan, Y. Kutlu, and N. Allahverdi, "Deep learning on computerized analysis of chronic obstructive pulmonary disease," *IEEE J. Biomed. Heal. Informatics*, vol. 24, no. 5, pp. 1344–1350, 2019.
- [6] Y. Feng, Y. Wang, C. Zeng, and H. Mao, "Artificial intelligence and machine learning in chronic airway diseases: focus on asthma and chronic obstructive pulmonary disease," *Int. J. Med. Sci.*, vol. 18, no. 13, p. 2871, 2021.
- [7] J. Peng, C. Chen, M. Zhou, X. Xie, Y. Zhou, and C.-H. Luo, "A machine-learning approach to forecast aggravation risk in patients with acute exacerbation of chronic obstructive pulmonary disease with clinical indicators," *Sci. Rep.*, vol. 10, no. 1, pp. 1–9, 2020.
- [8] G. Altan, Y. Kutlu, and A. Gökçen, "Chronic obstructive pulmonary disease severity analysis using deep learning on multi-channel lung sounds," *Turkish J. Electr. Eng. Comput. Sci.*, vol. 28, no. 5, pp. 2979–2996, 2020.
- [9] X. Ma *et al.*, "Comparison and development of machine learning tools for the prediction of chronic obstructive pulmonary disease in the Chinese population," *J. Transl. Med.*, vol. 18, pp. 1–14, 2020.
- [10] C.-T. Wu *et al.*, "Acute exacerbation of a chronic obstructive pulmonary disease prediction system using wearable device data, machine learning, and deep learning: development and cohort study," *JMIR mHealth uHealth*, vol. 9, no. 5, p. e22591, 2021.
- [11] A. Hussain, H.-E. Choi, H.-J. Kim, S. Aich, M. Saqlain, and H.-C. Kim, "Forecast the exacerbation in patients of chronic obstructive pulmonary disease with clinical indicators using machine learning techniques," *Diagnostics*, vol. 11, no. 5, p. 829, 2021.
- [12] C. Wang, X. Chen, L. Du, Q. Zhan, T. Yang, and Z. Fang, "Comparison of machine learning algorithms for the identification of acute exacerbations in chronic obstructive pulmonary disease," *Comput. Methods Programs Biomed.*, vol. 188, p. 105267, 2020.
- [13] D. Xu, X. Cui, and H. Xian, "An extended EDAS method with a single-valued complex neutrosophic set and its application in green supplier selection," *Mathematics*, vol. 8, no. 2, p. 282, 2020.
- [14] A. Kardeş, C. Kahraman, and E. Boltürk, "Interval-valued neutrosophic EDAS method: an application to prioritization of social responsibility projects," in *Fuzzy Multi-criteria Decision-Making Using Neutrosophic Sets*, Springer, 2019, pp. 455–485.
- [15] X. Peng and C. Liu, "Algorithms for neutrosophic soft decision making based on EDAS, new similarity measure and level soft set," *J. Intell. Fuzzy Syst.*, vol. 32, no. 1, pp. 955–968, 2017.
- [16] I. Irvanizam *et al.*, "An improved EDAS method based on bipolar neutrosophic set and its application in group decision-making," *Appl. Comput. Intell. Soft Comput.*, vol. 2021, pp. 1–16, 2021.
- [17] P. Wang, J. Wang, and G. Wei, "EDAS method for multiple criteria group decision making under 2-tuple linguistic neutrosophic environment," *J. Intell. Fuzzy Syst.*, vol. 37, no. 2, pp. 1597–1608, 2019.
- [18] Gopal Chaudhary, Manju Khari, Amena Mahmoud, Intelligent Video Moving Target Detection Based on Multi-Attribute Single Value Medium Neutrosophic Method, *Journal of Intelligent Systems and Internet of Things*, Vol. 5, No. 1, (2021) : 49-59 (Doi : <https://doi.org/10.54216/JISIoT.050105>) [19] D. Stanujkić *et al.*, "A single-valued neutrosophic extension of the EDAS method," *Axioms*, vol. 10, no. 4, p. 245, 2021.
- [20] Y. Li, J. Wang, and T. Wang, "A linguistic neutrosophic multi-criteria group decision-making approach with

- EDAS method.," *Arab. J. Sci. Eng. (Springer Sci. Bus. Media BV)*, vol. 44, no. 3, 2019.
- [21] S. Ashraf, S. Ahmad, M. Naeem, M. Riaz, and M. Alam, "Novel EDAS methodology based on single-valued neutrosophic Aczel-Alsina aggregation information and their application in complex decision-making," *Complexity*, vol. 2022, 2022.
- [22] Abdullallah Gamal , Nehal Nabil Mostafa, Sustainable Supplier Selection using Neutrosophic Sets and MCDM Framework, *Neutrosophic and Information Fusion*, Vol. 1 , No. 1 , (2023) : 27-33 (Doi : <https://doi.org/10.54216/NIF.010103>).
- [23] Ahmed Sleem , Ibrahim Elhenawy, An Interval Valued Neutrosophic Sets Integrated with the AHP MCDM Methodology to Assess the Station of 5G Network, *Neutrosophic and Information Fusion*, Vol. 1 , No. 1 , (2023) : 34-40 (Doi : <https://doi.org/10.54216/NIF.010104>).
- [24] A. A. Supciller and F. Toprak, "Selection of wind turbines with multi-criteria decision making techniques involving neutrosophic numbers: A case from Turkey," *Energy*, vol. 207, p. 118237, 2020.
- [25] Ahmed M. Ali, Ranking Renewable Energy Alternatives by using Triangular Neutrosophic Sets Integrated with MCDM, *Neutrosophic and Information Fusion*, Vol. 1 , No. 1 , (2023) : 17-26 (Doi : <https://doi.org/10.54216/NIF.010102>).
- [26] A. Karaşan and C. Kahraman, "A novel interval-valued neutrosophic EDAS method: prioritization of the United Nations national sustainable development goals," *Soft Comput.*, vol. 22, pp. 4891–4906, 2018.
- [27] C. S. Manigandaa , V. D. Ambeth Kumar , G. Ragunath , R. Venkatesan , N. Senthil Kumar, De-Noising and Segmentation of Medical Images using Neutrophilic Sets, *Fusion: Practice and Applications*, Vol. 11 , No. 2 , (2023) : 111-123 (Doi : <https://doi.org/10.54216/FPA.110208>).
- [28] Mahmoud Ismail , Shereen Zaki, Neutrosophic MCDM Methodology to Select Best Industrial Arc Welding Robot, *Neutrosophic and Information Fusion*, Vol. 1 , No. 1 , (2023) : 08-16 (Doi : <https://doi.org/10.54216/NIF.010101>).
- [29] Mehmet Merkepçi , Mohammad Abobala , Ali Allouf, The Applications of Fusion Neutrosophic Number Theory in Public Key Cryptography and the Improvement of RSA Algorithm, *Fusion: Practice and Applications*, Vol. 10 , No. 2 , (2023) : 69-74 (Doi : <https://doi.org/10.54216/FPA.100206>).
- [30] Ricardo, J. E., A. J. R. Fernández, M. Y. L. Vázquez. "Compensatory Fuzzy Logic with Single Valued Neutrosophic Numbers in the Analysis of University Strategic Management." *International Journal of Neutrosophic Science*, Vol. 18, pp. 151-159, 2022.
- [31] Gómez, Gustavo Adolfo Álvarez, Maikel Yelandi Leyva Vázquez, Jesús Estupiñán Ricardo. "Application of Neutrosophy to the Analysis of Open Government, its Implementation and Contribution to the Ecuadorian Judicial System." *Neutrosophic Sets and Systems* vol 52, pp.215-224., 2022.