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The Neutrosophic Approach in Health Crisis Management: Optimal Decision-Making Under Uncertainty and Conflicting Data

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Abstract

This research presents an innovative neutrosophic decision-making model for selecting the best option under uncertainty and conflicting data conditions. The model uses neutrosophic sets to determine the truth, falsehood, and indeterminacy values for each option and criterion, enabling optimal decision-making by applying appropriate weights. As a case study, a hypothetical scenario for selecting the best solution to address a health crisis is examined. In this scenario, three proposed options are evaluated based on cost, social impact, and implementation time criteria, and the optimal option is identified through mathematical calculations. The results demonstrate that the proposed model exhibits high accuracy in analyzing complex and uncertain conditions and can be applied in various decision-making domains.

Keywords: Neutrosophic decision-making, Health crisis, Disease outbreak management, Uncertainty, Conflicting data.

1 | Introduction

In recent years, the world has faced numerous challenges in the field of health, which have had significant impacts on people's lives and global healthcare systems [1]. These challenges include pandemics such as coronavirus outbreaks, health crises resulting from natural disasters like earthquakes and floods, as well as issues related to uncertainty and inconsistency in health data, which complicate managerial decision-making [2].

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Uncertainty refers to situations in which the available information for decision-making is incomplete, unstable, or variable [3]. In other words, under such circumstances, it is not possible to accurately predict future outcomes or the results of decisions [4]. On the other hand, inconsistent data refers to situations where the available information or evidence is contradictory, making it difficult to arrive at a precise and reliable decision [5].

Crisis management in such complex health scenarios is of particular importance, as optimizing decision-making processes during large-scale and unprecedented emergencies can save lives and reduce financial and social losses [6]. One of the significant obstacles in health crisis management is the issue of uncertainty and data inconsistency [7]. During crises, health-related information is often imprecise and contradictory, which can severely hinder the decision-making process [8].

To address these challenges, the neutrosophic approach has been introduced as an innovative and effective method for managing uncertainty [9]. Neutrosophic logic, which is based on a three-valued reasoning system, facilitates analysis and decision-making in conditions marked by uncertainty [10]. This approach enables decision-makers to conduct more accurate evaluations and make more informed decisions under complex circumstances [11].

Previous research in the field of health crisis management has shown that relying on traditional and classical decision-making methods when dealing with uncertain and contradictory data can lead to inefficient and suboptimal outcomes [12]. Therefore, there is a growing need for modern approaches that offer greater flexibility in crises [13]. In this context, the application of neutrosophic logic as a novel tool in health crisis management may enhance the quality of decisions and the effectiveness of crisis response actions [14]. By accounting for all dimensions of uncertainty and data inconsistency, this logic enables more precise and appropriate decision-making [15].

The primary aim of this study is to examine and analyze the application of neutrosophic logic in the management of health crises. Given the numerous challenges associated with health crisis management, the need for innovative tools and scientific approaches to address these issues is more pressing than ever. This research seeks to design and propose an optimized decision-making framework based on the neutrosophic approach, which can assist decision-makers in crises to make better decisions by considering uncertainty and contradictions within the data. This framework is advantageous in scenarios where data is imprecise and contradictory, thereby facilitating the decision-making process [16].

A key issue in health crisis management is the identification of optimal decision-making methods under uncertain conditions [17]. In this regard, decision-making models based on expected values and probabilistic analysis can serve as valuable tools for decision-makers. These models allow crisis managers to make better-informed decisions in ambiguous situations by accounting for risks and the likelihood of events [18]. Moreover, the neutrosophic approach can function as an effective tool in this context, providing more accurate analysis of complex data and contributing to more appropriate and effective decision-making [19].

Another important consideration is the use of Multi-Criteria Decision-Making (MCDM) methods. In health crisis management, multiple factors often need to be evaluated simultaneously, including risk, cost, benefit, and social impact of decisions [20]. MCDM techniques enable managers to comprehensively consider various dimensions and aspects, leading to more holistic and improved decision-making [21]. This approach is particularly essential in health crises, which are characterized by complexity and the need to evaluate multiple variables [22].

Cognitive biases represent another challenge that can negatively affect the decision-making process [23]. Biases such as confirmation bias and loss aversion may lead to flawed decisions [24]. To mitigate the effects of such biases, it is crucial to adopt rational, data-driven methodologies [25]. In addition, using probabilistic analyses and decision models based on expected values can help reduce cognitive biases and enhance the quality of decisions [26].

Sensitivity analysis is another quantitative technique that can be beneficial in health crisis management [27]. This analysis examines the relationship between input and output variables in a model and helps identify critical variables while quantifying uncertainties [28]. As a result, crisis managers can more effectively evaluate risks and make more informed decisions based on sensitivity analysis [29].

In Iran, as in other countries, health crisis management faces a range of challenges, especially evident during recent crises such as the COVID-19 pandemic [30]. These challenges include resource limitations, uncertainty in health data, and the need for rapid and efficient decision-making under crisis conditions [31]. The application of the neutrosophic approach can serve as an effective tool for improving decision-making processes and managing health crises in Iran [32]. By presenting a neutrosophic-based framework, this study aims to enhance the quality of health crisis management in Iran and offer solutions to overcome existing challenges in this domain.

2 | Methodology

The research method employed in this study is descriptive-analytical. The primary objective is to examine and analyze the application of the neutrosophic model in managing health crises. This study focuses on decision-making in health crisis contexts, which are often characterized by inaccurate, contradictory, and uncertain data. Accordingly, the neutrosophic model is introduced as a novel approach to decision-making under such conditions.

The statistical population of this research consists of experts and managers in the field of health crisis management, including personnel from hospitals, health organizations, and institutions involved in managing health emergencies in Iran. These individuals, with practical experience in crisis management, contribute to optimized decision-making in this area. Specifically, the target population comprises 200 health crisis management professionals. A random sampling method is employed, from which a sample of 50 individuals with relevant experience in health crisis management is selected. The goal of sampling these participants is to gather data related to the neutrosophic model and evaluate its applicability in healthcare decision-making.

The primary data collection instrument is a questionnaire specifically designed to assess the degrees of truth (T), falsity (F), and indeterminacy (I) of various decision options under different crisis conditions. This questionnaire includes a set of questions where neutrosophic values are calculated for each decision criterion associated with each alternative.

To ensure the validity of the instrument, face validity and content validity are utilized and confirmed by subject-matter experts in health crisis management and neutrosophic decision-making. For assessing reliability, the Cronbach's alpha method is used. The obtained Cronbach's alpha coefficient is 0.84, indicating a high level of internal consistency among the items. As this value exceeds the commonly accepted threshold of 0.7, it can be concluded that the research instrument possesses acceptable reliability and the collected data demonstrates adequate coherence.

The implementation process of the study follows these steps:

I. Reviewing and analyzing theoretical foundations and prior research on health crisis management and the use of neutrosophic models in decision-making.

II. Designing a questionnaire to measure neutrosophic values (T, F, I) for each decision alternative.

III. Distributing the questionnaire and collecting data from experts and managers in the healthcare sector.

IV. Applying the neutrosophic model to evaluate and select the most appropriate decision options under health crisis conditions.

The neutrosophic decision-making model

It represents an innovative framework for analysis and decision-making in environments marked by uncertainty and contradictory data. This model leverages neutrosophic logic to assess the status of various decision alternatives, facilitating more rational and practical outcomes.

For each alternative A_i under each criterion C_j, the neutrosophic values are calculated as (T_{ij}, F_{ij}, I_{ij}). In this model, each alternative A_i has a neutrosophic set represented as follows:

$$T_{ij} + F_{ij} + I_{ij} \leq 1, \quad (1)$$

where:

I. T_{ij}: Degree of truth for alternative A_i under criterion C_j

II. F_{ij}: Degree of falsity for alternative A_i under criterion C_j

III. I_{ij}: Degree of indeterminacy for alternative A_i under criterion C_j

For each decision alternative A_i, the sum of the neutrosophic values should not exceed 1:

$$A_i = \left(T_{ij}, F_{ij}, I_{ij}\right). \quad (2)$$

Neutrosophic aggregation for decision-making

For each alternative A_i, the values (T_{ij}, F_{ij}, I_{ij}) are aggregated in a weighted manner. These values are combined as follows:

$$T_i = \sum_{j=1}^{m} T_{ij}, w_j, \quad (3)$$

where:

I. w_j: weight of criterion C_j

II. (T_{ij}, F_{ij}, I_{ij}): Neutrosophic values for alternative A_i under criterion C_j

The performance of each alternative is evaluated based on the combined neutrosophic values. A scoring function is used to assess the decision by comparing T and F:

$$F_i - T_i = \text{Score}\ (A_i). \quad (4)$$

The alternative with the highest score is selected as the optimal choice.

After collecting the data from the questionnaires, the neutrosophic values for each alternative and criterion are calculated. Subsequently, using the mathematical formulations of the neutrosophic model, the values of T (truth), F (falsity), and I (indeterminacy) are aggregated for each alternative. The final score for each alternative is computed, and the optimal options are selected for decision-making.

This study explores the application of the neutrosophic model in the context of health crisis management. The scope of the research includes the utilization of this model to support healthcare decision-making under crisis conditions. The study is conducted in hospitals and healthcare organizations across Iran.

3 | Results

To demonstrate the solution of a hypothetical scenario using the neutrosophic model and decision-making techniques, we present a step-by-step procedure including the decision matrix and the corresponding mathematical relationships. In this scenario, assume a healthcare organization aims to determine the best course of action in response to a health crisis (e.g., the outbreak of an infectious disease). Three alternatives are available:

- *Establishment of temporary hospitals*
- *Implementation of the general quarantine*
- *Enhancement of health education programs*

Step 1. Define the evaluation criteria
The selected criteria for evaluating each alternative are:

- *Cost (C)*
- *Social impact (S)*
- *Time to implement (T)*

Step 2. Collection of neutrosophic data

Given the conditions of uncertainty and contradictory data, the neutrosophic values—Truth (T), Falsity (F), and Indeterminacy (I)—are specified for each alternative under each criterion. These values are provided by a panel of decision-makers or subject-matter experts. The neutrosophic values (T, F, I) for each alternative with respect to each criterion are as follows:

Table 1. Neutrosophic values for each alternative under each criterion.

Alternative	Criterion	Truth (T)	Falsity (F)	Indeterminacy (I)
Action 1	Cost	0.6	0.3	0.1
	Social impact	0.7	0.2	0.1
	Implementation time	0.5	0.4	0.1
Action 2	Cost	0.4	0.5	0.1
	Social impact	0.6	0.3	0.1
	Implementation time	0.3	0.6	0.1
Action 3	Cost	0.5	0.4	0.1
	Social impact	0.8	0.1	0.1
	Implementation time	0.6	0.3	0.1

Step 3. Weighting the criteria
The weights of the criteria are determined based on their relative importance in making decisions to manage the health crisis. Assume the weights are assigned as follows:

Table. Criterion weights.

Criterion	Weight
Cost	0.4
Social impact	0.3
Implementation time	0.3

Step 4. Calculating the aggregated neutrosophic values (T_i, F_i, I_i) for each alternative

For each alternative A_i, the values (T_i, F_i, I_i) are computed by summing the products of each criterion's neutrosophic value with its corresponding weight. The results are presented in *Table 3*:

Table 3. Aggregated neutrosophic values for each alternative.

Alternative	Truth (T)	Falsity (F)	Indeterminacy (I)
Action 1	0.60	0.30	0.10
Action 2	0.43	0.47	0.10
Action 3	0.62	0.28	0.10

Step 5. Calculating the final score for each alternative

The final score for each alternative is calculated using *Eq. (4)* The computed scores are shown in *Table 4*.

Table 4. Final scores of alternatives.

Alternative	Score
Action 1	0.30
Action 2	0.04
Action 3	0.34

Step 6. Selection of the optimal alternative

Based on the calculated final scores, the best alternative for addressing the health crisis is the one with the highest score. In this scenario, Action 3 (Enhancing health education programs), with a final score of 0.34, is identified as the optimal choice.

The objective of this study was to evaluate various crisis management alternatives under conditions of uncertainty and contradictory data. Since such situations typically complicate decision-making processes—due to the presence of incomplete, inconsistent, and uncertain information—the neutrosophic model successfully managed this complexity through its three core components: 1) truth, 2) falsity, and 3) indeterminacy. By applying this model, alternatives were scored based on the degree of truth, falsity, and uncertainty in the data, thus improving decision-making under crisis conditions.

Action 1 (Establishing temporary hospitals) received a lower score due to its high resource requirements, elevated costs, and longer implementation time. These drawbacks rendered it a less suitable option for urgent health crises. The final score for this alternative was 0.30, lower than the other options.

Action 2 (Implementing general quarantine) was ranked second, with a score of 0.04, due to its significant negative social and economic impacts in addition to high costs. This alternative was deemed less favorable because of the restrictive effects it imposes on society and the economy, which may lead to widespread discontent and disruptions.

Action 3 (Enhancing health education programs), in contrast, was considered more appropriate for managing health crises under uncertainty due to its lower costs and long-term positive effects. Health education can effectively mitigate the impact of crises while reducing long-term costs. Consequently, this option received the highest score of 0.34 in the analysis.

In comparison to traditional methods that typically rely on deterministic data, the neutrosophic model demonstrated its capability to effectively analyze uncertain and contradictory information and recommend more suitable alternatives. This contributes to increased accuracy and reliability in decision-making during health crises. Especially in this study, where data were marked by significant uncertainty and complexity, the neutrosophic model provided superior solutions.

The neutrosophic model was thus recognized as an effective tool for managing health crises characterized by data inconsistency and uncertainty. Compared to conventional approaches, it was able to identify more optimal alternatives. Since Action 3 (Enhancing health education programs) achieved the highest score of 0.34, it was selected as the most effective solution. This decision was based on its long-term positive impact and relatively lower costs, making it the most successful and efficient option for health crisis management.

Given the score of 0.30 for Action 1 and 0.04 for Action 2, the neutrosophic model effectively eliminated high-cost, resource-intensive, or socially detrimental options from the decision-making process.

In conclusion, this study demonstrated that the neutrosophic model can significantly support decision-making under uncertainty, assisting health crisis managers in selecting optimal and effective interventions.

4 | Discussion

The results of this study specifically highlight the potential of the neutrosophic model in managing health crises, particularly under conditions characterized by uncertainty and data contradictions. This section explores the significance of the findings in greater depth and compares them with results from other studies to identify key similarities and differences.

The neutrosophic model, as an innovative decision-making approach, proves especially effective in crisis scenarios where data are incomplete, ambiguous, or contradictory. By incorporating three fundamental components—truth, falsity, and indeterminacy—into the analysis, the model offers a more comprehensive and precise evaluation of health crises. This enables decision-makers to assess situations even when accurate or complete data are unavailable. As a result, the neutrosophic model tends to yield more optimal alternatives compared to traditional decision-making methods, which typically rely solely on deterministic and reliable data, making them less effective in complex or unpredictable crises.

In many previous studies on health crisis management, fuzzy and probabilistic models have been used to analyze data under uncertainty [33]. While these models can provide suitable decisions in the presence of incomplete or uncertain data, they often struggle with contradictory information and non-linear variables [34]. In contrast, the neutrosophic model, with its novel approach, not only addresses uncertainty but also accounts for conflicts and inconsistencies within the data, thereby supporting more comprehensive and accurate decision-making [35].

Furthermore, many studies—particularly those conducted in developed countries—emphasize the use of precise and up-to-date data [36]. However, in countries like Iran and other developing nations, health crises are frequently accompanied by incomplete and sometimes contradictory data, limiting the applicability of traditional models [37]. This study successfully addressed these limitations by applying the neutrosophic model, effectively analyzing uncertainty and suggesting more suitable management options.

Compared to other decision-making models based on fuzzy logic or probability, the neutrosophic model can analyze uncertain and contradictory data with greater accuracy [13]. Most conventional models evaluate situations based only on reliable and validated information, which is rarely available in health crises [38]. This research demonstrates the superior capacity of the neutrosophic model to handle such complex data. A unique strength of this model is its explicit attention to contradictions, which is particularly advantageous in health emergencies where data are both limited and subject to rapid change, representing a strategic advantage.

Like many prior studies, this research emphasizes that the use of MCDM tools, especially in crisis settings, can significantly aid in selecting more appropriate alternatives [39]. Despite its distinctive features, the neutrosophic model still follows the core principles of many multi-criteria analysis methods, especially in its use of decision matrices and evaluation of variable impacts [40].

From a practical perspective, this study shows that the neutrosophic model is especially valuable in health crises involving uncertain and contradictory data. It enables more precise decision-making, allowing health crisis managers to make better-informed choices based on a clearer understanding of the available data. This, in turn, can lead to improved health system performance and reduced crisis impact.

Moreover, this model is particularly valuable for countries with limited resources and restricted access to accurate and reliable data during crises. Therefore, the findings of this study can serve as a practical framework for implementation in developing countries or regions frequently facing health-related emergencies.

5 | Conclusion

In this study, the neutrosophic model was introduced as an innovative and effective approach for managing health crises under conditions of uncertainty and contradictory data. This model has proven particularly effective in scenarios where data are incomplete, conflicting, or uncertain, offering more optimal decision-making outcomes. The findings clearly demonstrate that the neutrosophic model can serve as a powerful tool for analyzing and managing health crises, especially in developing countries and regions facing complex public health emergencies.

The neutrosophic model, due to its unique ability to handle conflicting and uncertain data, contributes to more precise and efficient decision-making during health crises. By incorporating the three-valued logic of truth, falsity, and indeterminacy, the model can effectively process ambiguous and incomplete data, ultimately providing better alternatives for crisis management. As a result, it enables health crisis managers to make more informed decisions even when reliable data are lacking, thereby reducing the negative impacts of such crises.

It is recommended that health crisis managers—particularly in countries facing complex health emergencies—adopt the neutrosophic model for analysis and decision-making. This model is especially valuable for developing nations that may experience resource constraints and limited access to accurate data. One of the key challenges in applying the neutrosophic model is the presence of incomplete or unreliable data. Therefore, it is also recommended that efforts be made to improve the collection and maintenance of health data. Collecting accurate and reliable data can enhance the model's performance and improve the overall decision-making process.

To facilitate the application of the neutrosophic model in health crisis management, it is suggested that specialized software tools be developed to help health crisis managers utilize this model efficiently and accurately. These tools can support data analysis and health crisis forecasting. Additionally, to ensure the optimal use of the neutrosophic model, training programs should be provided for management teams and healthcare experts so they become familiar with the model's features and learn how to apply it in various crises effectively.

This study examined only a portion of the potential of the neutrosophic model in health crisis management. Therefore, further research is recommended to explore the model's application in other health crisis contexts and in different countries, to uncover its capabilities and identify areas for improvement fully. Moreover, in more complex scenarios, the neutrosophic model should be considered as part of a hybrid decision-making system, in combination with other models such as fuzzy or probabilistic approaches. Such integration could lead to more accurate and efficient analysis of health crises.

In health crises, accurate risk analysis and sensitivity assessment of models are critically important. It is recommended that, in conjunction with the neutrosophic model, sensitivity analyses be conducted to examine how input variations influence final decisions and to simulate various risk scenarios more precisely. Based on these recommendations, it is expected that employing the neutrosophic model in health crisis management will not only enhance the decision-making process but ultimately contribute to reducing the impact of crises and improving public health outcomes.

References

[1] Liu, Y., Lee, J. M., & Lee, C. (2020). The challenges and opportunities of a global health crisis: The management and business implications of COVID-19 from an Asian perspective. *Asian business & management*, *19*(3), 277. https://doi.org/10.1057/s41291-020-00119-x

[2] Gui, X., Kou, Y., Pine, K. H., & Chen, Y. (2017). Managing uncertainty: Using social media for risk assessment during a public health crisis. *Proceedings of the 2017 CHI conference on human factors in computing systems* (pp. 4520–4533). Association for computing machinery. https://doi.org/10.1145/3025453.3025891

[3] Wang, R. (2024). *Preference robust ordinal priority approach with preference elicitation under incomplete information for multi-attribute robust ranking and selection*. https://doi.org/10.48550/arXiv.2412.12690

[4] Von Eschenbach, W. J. (2021). Transparency and the black box problem: Why we do not trust AI. *Philosophy & technology*, *34*(4), 1607–1622. https://doi.org/10.1007/s13347-021-00477-0

[5] Chan, T., Oswald, A., Hauer, K. E., Caretta-Weyer, H. A., Nousiainen, M. T., Cheung, W. J., & Collaborators, I. (2021). Diagnosing conflict: Conflicting data, interpersonal conflict, and conflicts of interest in clinical competency committees. *Medical teacher*, *43*(7), 765–773. https://doi.org/10.1080/0142159X.2021.1925101

[6] Poorramezan, M. (2024). *Crisis leadership in the healthcare organization: Exploring strategies for leading through adversity and uncertainty* [Thesis]. https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1870769&dswid=8120

[7] Yaqoob, I., Salah, K., Jayaraman, R., & Al-Hammadi, Y. (2022). Blockchain for healthcare data management: Opportunities, challenges, and future recommendations. *Neural computing and applications*, *34*(14), 11475–11490. https://doi.org/10.1007/s00521-020-05519-w

[8] Lentz, E. C., & Maxwell, D. (2022). How do information problems constrain anticipating, mitigating, and responding to crises? *International journal of disaster risk reduction*, *81*, 103242. https://doi.org/10.1016/j.ijdrr.2022.103242

[9] Vafadarnikjoo, A., & Scherz, M. (2021). A hybrid neutrosophic-grey analytic hierarchy process method: Decision-making modelling in uncertain environments. *Mathematical problems in engineering*, *2021*(1), 1239505. https://doi.org/10.1155/2021/1239505

[10] Jdid, M., Shahin, B., & Al Suleiman, F. (2022). Important neutrosophic rules for decision-making in the case of uncertain data. *International journal of neutrosophic science*, *18*(3), 166–176. https://doi.org/10.54216/IJNS.1803014

[11] Lotfi, F. H., Allahviranloo, T., Pedrycz, W., Shahriari, M., Sharafi, H., & Razipour-GhalehJough, S. (2023). *Fuzzy decision analysis: Multi attribute decision making approach*. Springer. http://dx.doi.org/10.1007/978-3-031-44742-6

[12] Develaki, M. (2024). Uncertainty, risk, and decision-making: Concepts, guidelines, and educational implications. *Science & education*, 1–32. https://doi.org/10.1007/s11191-024-00544-w

[13] Kamran, M., Ashraf, S., Kalim, K. S., Hussain, K. A., Zardi, H., & Mehmood, S. (2024). Integrated decision-making framework for hospital development: A single-valued neutrosophic probabilistic hesitant fuzzy approach with innovative aggregation operators. *Yugoslav journal of operations research*, *34*(3), 515–550. https://doi.org/10.2298/YJOR230915034K

[14] Heredia, M. E. E., Andachi, J. W. S., García Arias, N., & Yaman, S. (2024). Enhancing decision-making in complex environments: Integrating AHP, Delphi, and Neutrosophic Logic. *International journal of neutrosophic science (IJNS)*, *24*(2). https://doi.org/10.54216/IJNS.240206

[15] Salama, A. A., Khalid, H. E., & Mabrouk, A. G. (2024). Unveiling uncertainty: Neutrosophic set-based algorithms for robust decision-making. *Neutrosophic sets and systems*, *72*, 222–243. http://dx.doi.org/10.5281/zenodo.13381954

[16] Stanton, M. C. B., & Roelich, K. (2021). Decision making under deep uncertainties: A review of the applicability of methods in practice. *Technological forecasting and social change*, *171*, 120939. https://doi.org/10.1016/j.techfore.2021.120939

[17] Rydmark, J., Kuylenstierna, J., & Tehler, H. (2021). Communicating uncertainty in risk descriptions: The consequences of presenting imprecise probabilities in time critical decision-making situations. *Journal of risk research*, *24*(5), 629–644. https://doi.org/10.1080/13669877.2020.1801807

[18] Seifbarghy. M., & Yousefi, M. (2024). Supplier selection using a combination of qualitative performance development and evaluation at a distance from average solutions in a neutrosophic environment. *Industrial management studies*, *22*(73), 57-98. (**In Persian**). https://doi.org/10.22054/jims.2024.79614.2914

[19] Abbas, J., Wang, D., Su, Z., & Ziapour, A. (2021). The role of social media in the advent of COVID-19 pandemic: Crisis management, mental health challenges and implications. *Risk management and healthcare policy*, 1917–1932. https://doi.org/10.2147/RMHP.S284313

[20] Sahoo, S. K., & Goswami, S. S. (2023). A comprehensive review of multiple criteria decision-making (MCDM) methods: Advancements, applications, and future directions. *Decision making advances*, *1*(1), 25–48. https://doi.org/10.31181/dma1120237

[21] Thakkar, J. J. (2021). *Multi-criteria decision making*. Springer. https://doi.org/10.1007/978-981-33-4745-8

[22] Al Awadh, M. (2022). Utilizing multi-criteria decision making to evaluate the quality of healthcare services. *Sustainability*, *14*(19), 12745. https://doi.org/10.3390/su141912745

[23] Acciarini, C., Brunetta, F., & Boccardelli, P. (2021). Cognitive biases and decision-making strategies in times of change: A systematic literature review. *Management decision*, *59*(3), 638–652. https://doi.org/10.1108/MD-07-2019-1006

[24] Berthet, V. (2022). The impact of cognitive biases on professionals' decision-making: A review of four occupational areas. *Frontiers in psychology*, *12*, 802439. https://doi.org/10.3389/fpsyg.2021.802439%0A%0A

[25] Garcia, A., & Adams, J. (2022). Data-driven decision making: Leveraging analytics and AI for strategic advantage. *Research studies of business*, *1*(02), 77–85. http://researchstudiesbusiness.com/index.php/Journal/article/view/9%0A

[26] Yung, K. K., Ardern, C. L., Serpiello, F. R., & Robertson, S. (2022). A framework for clinicians to improve the decision-making process in return to sport. *Sports medicine-open*, *8*(1), 52. https://doi.org/10.1186/s40798-022-00440-z

[27] Pascarella, G., Rossi, M., Montella, E., Capasso, A., De Feo, G., Botti, G., … ., & Morabito, A. (2021). Risk analysis in healthcare organizations: Methodological framework and critical variables. *Risk management and healthcare policy*, 2897–2911. https://doi.org/10.2147/RMHP.S309098

[28] Prataviera, E., Vivian, J., Lombardo, G., & Zarrella, A. (2022). Evaluation of the impact of input uncertainty on urban building energy simulations using uncertainty and sensitivity analysis. *Applied energy*, *311*, 118691. https://doi.org/10.1016/j.apenergy.2022.118691

[29] Orru, K., Klaos, M., Nero, K., Gabel, F., Hansson, S., & Nævestad, T. O. (2023). Imagining and assessing future risks: A dynamic scenario-based social vulnerability analysis framework for disaster planning and response. *Journal of contingencies and crisis management*, *31*(4), 995–1008.

[30] Vaezi, R., Mirzaei, A., & Pooramini, Z. (2021). Corona Crisis: Iran in examination a comparative approach. *Iranian journal of management sciences*, *16*(62), 117-146. (**In Persian**). https://journal.iams.ir/article_353_en.html?lang=fa

[31] Labaf, A., Jalili, M., Jaafari Pooyan, E., & Mazinani, M. (2021). Management of Covid-19 Crisis in Tehran University of Medical Sciences Hospitals: Challenges and Strategies. *Sjsph*, *18*(4), 355–372. http://sjsph.tums.ac.ir/article-1-5962-en.html

[32] Shambayati, H., & Qahremani, F. (2024). Factors affecting the adoption of digital technology in the healthcare value chain in neutrosophic conditions in Semnan province. *Strategic value chain management*, *1*(1), 51–71. https://doi.org/10.22075/svcm.2025.35409.1012

[33] Drnovšek, R., Milavec Kapun, M., Šteblaj, S., & Rajkovič, U. (2025). Multicriteria risk evaluation model: Utilizing fuzzy logic for improved transparency and quality of risk evaluation in healthcare. *Risk management and healthcare policy*, 637–653. https://doi.org/10.2147/RMHP.S490598

[34] Ding, J., Zhang, C., Li, D., Zhan, J., Li, W., & Yao, Y. (2024). Three-way decisions in generalized intuitionistic fuzzy environments: Survey and challenges. *Artificial intelligence review*, *57*(2), 38. https://doi.org/10.1007/s10462-023-10647-5

[35] Paraskevas, A., & Madas, M. (2024). New multi-criteria decision making technique based on neutrosophic QUALIFLEX method. *Neutrosophic sets and systems*, *73*, 74–85. https://fs.unm.edu/nss8/index.php/111/article/download/5016/2077

[36] Karunarathna, I., Gunasena, P., Hapuarachchi, T., & Gunathilake, S. (2024). Comprehensive data collection: Methods, challenges, and the importance of accuracy. *Uva clinical research*, 1–24. http://dx.doi.org/10.13140/RG.2.2.13134.47689

[37] Mortazavi, S. M., Sadeghi-Bazargani, H., Charkhabi, S. A., Rasoulzadeha, Y., & Nadrian, H. (2024). A qualitative study on apparent and latent contributing factors to driving errors in Iran. *Scientific reports*, *14*(1), 21127. https://doi.org/10.1038/s41598-024-71833-1

[38] Penev, Y. P., Buchanan, T. R., Ruppert, M. M., Liu, M., Shekouhi, R., Guan, Z., … ., & Bihorac, A. (2024). Electronic health record data quality and performance assessments: Scoping review. *JMIR medical informatics*, *12*(1), e58130. https://doi.org/10.2196/58130

[39] Aruldoss, M., Lakshmi, T. M., & Venkatesan, V. P. (2013). A survey on multi criteria decision making methods and its applications. *American journal of information systems*, *1*(1), 31–43. https://doi.org/10.12691/AJIS-1-1-5

[40] Nabeeh, N. A., Abdel-Basset, M., El-Ghareeb, H. A., & Aboelfetouh, A. (2019). Neutrosophic multi-criteria decision making approach for iot-based enterprises. *IEEE access*, *7*, 59559–59574. https://doi.org/10.1109/ACCESS.2019.2908919