Neutrosophic Sets and Systems {Special Issue: Neutrosophic Advancements And Their Impact on Research in Latin America}, Vol. 62, 2023
University of New Mexico

Neutrosophic Modeling of Healthcare Resource Allocation

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Abstract. The main purpose of this study consisted in the implementation of neutrosophic logic as the central axis for the creation of a neutrosophic model, supported by the AHP method, for the allocation of beds in the Intensive Care Unit (ICU) of an emergency room located in the city of Babahoyo. The principles and contributions of neutrosophic logic are introduced and applied to effectively deal with the uncertainty and ambiguity inherent to resource allocation in a highly complex hospital environment. The synergy between the AHP methodology and the approaches proposed by neutrosophy has allowed the formulation of a model that enables informed and equitable decision-making in circumstances characterized by a shortage of ICU beds. This model ensures not only the provision of optimal care to patients but also the effective management of available resources. The results of this study not only confirm the effectiveness of neutrosophic logic in the scientific field for solving complex problems but also highlight its relevance in clinical practice in the hospital context.

Keywords: Neutrosophy, resource allocation, Intensive Care Unit, AHP method, hospital decision making.

1 Introduction

The usefulness and relevance of a correct decision-making process in the scientific and business context are fundamental to guarantee success and efficiency in achieving objectives. Effective decision-making is based on the systematic collection and critical evaluation of data, allowing individuals and organizations to select the best alternative among multiple available options [1]. This process is essential in strategic planning, resource management, and complex problem-solving.[2]

However, real-life decision-making faces undeniable complexity due to the indeterminacies and inaccuracies that often accompany available data. In an ideal world, decisions would be based on perfectly accurate and complete data, but in practice, data is often incomplete, ambiguous, or even incorrect [3]. Indeterminacies in the data can arise from various sources, such as measurement errors, lack of information, or the very nature of the phenomena under study. This inherent uncertainty can make it difficult to accurately evaluate situations and predict outcomes. [4]

In such a context, the creation and implementation of fuzzy logic represented a significant advance in the search for solutions to address indeterminacies in data in the field of artificial intelligence and decision-making. Fuzzy logic, developed by mathematician Lotfi A. Zadeh in the 1960s, is based on the premise that in many real-world situations, concepts, and variables cannot be defined in a precise binary (true/false) or numerical way, but rather have fuzzy degrees of membership.[5]

This logic introduces the idea of fuzzy values that allow the representation of uncertainty and ambiguity in data in a more realistic way. Through fuzzy operators, such as "and", "or", and "not", fuzzy logic can model and manipulate imprecise relationships between variables. This makes it a valuable tool for decision-making in uncertain conditions [6]. However, fuzzy logic focuses on the representation of fuzzy degrees of membership but lacks an adequate mechanism to handle deep ambiguity and indeterminacies in contexts where information is incomplete or conflicting.[7]

In the 1990s, mathematician and philosopher Florentin Smarandache proposed neutrosophic logic as a solution to problems with complex uncertainty. Neutrosophic logic was developed to overcome the limitations of fuzzy logic, especially when dealing with situations where there is not only uncertainty, but also paradox, neutral, and sometimes conflicting information in the data.[8]

This logic incorporates three main elements: true, false, and neutral, which allows uncertainty to be represented beyond the fuzzy, that is, in situations in which the information is incomplete or contradictory. [9] Neutrosophic logic provides a more comprehensive approach to dealing with ambiguity and indeterminacies in data and has been applied in areas such as artificial intelligence, decision-making, and risk-taking in complex and multifaceted scenarios.[10]

The applications of neutrosophic logic in complex decision-making extend to various fields of industry, business, and science due to its ability to deal with situations where uncertainty, ambiguity, and contradictory information challenge traditional methodologies. In industry, neutrosophic logic can be applied in risk management, such as in the evaluation of investment projects, where the available information may be partial and contradictory [11]. In business, this logic can be valuable for making strategic decisions, such as expanding markets in uncertain environments [12] or the management of complex supply chains.[13]

In the sciences, neutrosophic logic can be used in fields such as biomedicine, where the evaluation of the effectiveness of medical treatments can be affected by incomplete or inconsistent data. Its potential lies in its ability to model and analyze deep uncertainty, allowing professionals to make more informed and adaptive decisions in complex and multifaceted contexts. Neutrosophic logic represents a significant extension of available decision-making tools and has the potential to address challenges that go beyond the limits of traditional fuzzy logic.[14]

In the hospital setting, decision-making is of critical importance and is considered an essential process to ensure the efficiency, quality, and safety of medical care. In this context, decisions have direct consequences on the life and well-being of patients, as well as on the management of hospital resources. In cases of emergencies, or during a shortage of certain resources, decisions for their correct allocation are decisive in saving lives and guaranteeing the continuity of the process with adequate quality. In this context, multi-criteria analysis and cost evaluation methods are used to guarantee that resources are used effectively and equitably, considering criteria of interest for the resolution of these problems.[15-20]

The objective of this study is the application of neutrosophic logic as a fundamental way to create a neutrosophic model supported by the AHP method for the allocation of beds in the ICU of an emergency room in the city of Babahoyo. To do this, it was decided to apply the AHP method (Analytic Hierarchy Process), a multi-criteria decision-making technique widely used in resource management. Neutrosophic logic is introduced to address the uncertainty and ambiguity inherent in resource allocation in a hospital setting, where the availability of critical resources may be limited and information on patient acuity may be incomplete or contradictory. The combination of neutrosophic logic and the AHP method seeks to provide a robust and flexible tool for making informed and equitable decisions in situations of medical resource scarcity, ensuring optimal patient care and efficient management of available resources.

2 Method

2.1 Neutrosophic definitions

Definition 1: The *Neutrosophic set* N is characterized by three membership functions, which are the truth-membership function T_A, indeterminacy-membership function I_A, and falsehood-membership function F_A, where U is the Universe of Discourse and $\forall x \in U$, $T_A(x), I_A(x), F_A(x) \subseteq]^-0, 1^+[$, and $^-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+$. [8]

Notice that, according to the definition, $T_A(x)$, $I_A(x)$, and $F_A(x)$ are real standard or non-standard subsets of $]^-0, 1^+[$ and hence, $T_A(x)$, $I_A(x)$ and $F_A(x)$ can be subintervals of [0, 1].

Definition 2: The *Single-Valued Neutrosophic Set* (SVNS) N over U is $A = \{<x; T_A(x), I_A(x), F_A(x)>: x \in U\}$c, where $T_A: U \rightarrow [0, 1]$, $I_A: U \rightarrow [0, 1]$, and $F_A: U \rightarrow [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The *Single-Valued Neutrosophic Number* (SVNN) is represented by N = (t, i, f), such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3: [16] The *single-valued trapezoidal neutrosophic number*, $\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy, and falsehood membership functions are defined as follows, respectively:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, \quad a_2 \leq x \leq a_3 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), a_3 \leq x \leq a_4 \\ 0, \quad otherwise \end{cases} \tag{1}$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\beta_{\tilde{a}}(x-a_1))}{a_2-a_1}, \quad a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, \quad a_2 \leq x \leq a_3 \\ \frac{(x-a_2+\beta_{\tilde{a}}(a_3-x))}{a_3-a_2}, \quad a_3 \leq x \leq a_4 \\ 1, \quad \text{otherwise} \end{cases} \tag{2}$$

$$F_{\tilde{a}}(x)=\begin{cases}\frac{(a_2-x+\gamma_{\tilde{a}}(x-a_1))}{a_2-a_1}, & a_1\le x\le a_2\\ \gamma_{\tilde{a}}, & a_2\le x\le a_3\\ \frac{(x-a_2+\gamma_{\tilde{a}}(a_3-x))}{a_3-a_2}, & a_3\le x\le a_4\\ 1, & \text{otherwise}\end{cases} \quad (3)$$

Where $\alpha_{\tilde{a}},\beta_{\tilde{a}},\gamma_{\tilde{a}}\in[0,1]$, $a_1, a_2, a_3, a_4 \in \mathbb{R}$ and $a_1\le a_2\le a_3\le a_4$.

Definition 4: given $\tilde{a}=\langle(a_1,a_2,a_3,a_4);\alpha_{\tilde{a}},\beta_{\tilde{a}},\gamma_{\tilde{a}}\rangle$ and $\tilde{b}=\langle(b_1,b_2,b_3,b_4);\alpha_{\tilde{b}},\beta_{\tilde{b}},\gamma_{\tilde{b}}\rangle$ two single-valued trapezoidal neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

Addition: $\tilde{a}+\tilde{b}=\langle(a_1+b_1,a_2+b_2,a_3+b_3,a_4+b_4);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\rangle$

Subtraction: $\tilde{a}-\tilde{b}=\langle(a_1-b_4,a_2-b_3,a_3-b_2,a_4-b_1);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\rangle$ (4)

Inversion: $\tilde{a}^{-1}=\langle(a_4{}^{-1},a_3{}^{-1},a_2{}^{-1},a_1{}^{-1});\alpha_{\tilde{a}},\beta_{\tilde{a}},\gamma_{\tilde{a}}\rangle$, where $a_1,a_2,a_3,a_4\neq 0$.

Multiplication by a scalar number:

$$\lambda\tilde{a}=\begin{cases}\langle(\lambda a_1,\lambda a_2,\lambda a_3,\lambda a_4);\alpha_{\tilde{a}},\beta_{\tilde{a}},\gamma_{\tilde{a}}\rangle, & \lambda>0\\ \langle(\lambda a_4,\lambda a_3,\lambda a_2,\lambda a_1);\alpha_{\tilde{a}},\beta_{\tilde{a}},\gamma_{\tilde{a}}\rangle, & \lambda<0\end{cases} \quad (5)$$

2.2 Neutrosophic AHP

Definitions 3 and 4 refer to single-valued triangular neutrosophic numbers when the condition a2 = a3, For simplicity, the linguistic scale of triangular neutrosophic numbers is used, see Table 1 and also compare with the scale defined in [17-22-23-24].

Table 1: Saaty's scale translated into a neutrosophic triangular scale.

Saaty's scale	Definition	Neutrosophic Triangular Scale
1	Equally influential	$\tilde{1}=\langle(1,1,1);0.50,0.50,0.50\rangle$
3	Slightly influential	$\tilde{3}=\langle(2,3,4);0.30,0.75,0.70\rangle$
5	Strongly influential	$\tilde{5}=\langle(4,5,6);0.80,0.15,0.20\rangle$
7	Very strongly influential	$\tilde{7}=\langle(6,7,8);0.90,0.10,0.10\rangle$
9	Absolutely influential	$\tilde{9}=\langle(9,9,9);1.00,1.00,1.00\rangle$
2, 4, 6, 8	Sporadic values between two close scales	$\tilde{2}=\langle(1,2,3);0.40,0.65,0.60\rangle$
		$\tilde{4}=\langle(3,4,5);0.60,0.35,0.40\rangle$
		$\tilde{6}=\langle(5,6,7);0.70,0.25,0.30\rangle$
		$\tilde{8}=\langle(7,8,9);0.85,0.10,0.15\rangle$

The analytic hierarchy process AHP was proposed by Thomas Saaty in 1980. This technique models the problem that leads to the formation of a hierarchy representative of the associated decision-making scheme. The formulation of the decision-making problem in a hierarchical structure is the first and main stage. This stage is where the decision maker must break down the problem into its relevant components. The hierarchy is constructed so that the elements are of the same order of magnitude and can be related to some of the next level. In a typical hierarchy, the highest level locates the problem of decision-making. The elements that affect decision-making are represented at the intermediate level, the criteria occupying the intermediate levels. At the lowest level, the decision options are understood. The levels of importance or weighting of the criteria are estimated through paired comparisons between them. This comparison is carried out using a scale, as expressed in equation 6.

$$S=\left\{\frac{1}{9},\frac{1}{7},\frac{1}{5},\frac{1}{3},1,3,5,7,9\right\} \quad (6)$$

[18] address the theory of the AHP technique in a neutrosophic framework. Thus, the indeterminacy of decision-making can be modeled by applying neutrosophic AHP, or NAHP for short. Equation 7 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

$$\tilde{A}=\begin{bmatrix}\tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n}\\ \vdots & & \ddots & \vdots\\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1}\end{bmatrix} \quad (7)$$

The matrix must satisfy the condition $\tilde{A}\tilde{a}_{ji}=\tilde{a}_{ij}^{-1}$, based on the inversion operator of Definition 4.

To convert neutrosophic triangular numbers into crisp numbers, there are two indexes defined by [19-21], they are the so-called score and accuracy indexes, respectively, see Equations 8 and 9:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{8}$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \tag{9}$$

Neutrosophic AHP steps

Step 1: Select a group of experts.

Step 2: Structure the neutrosophic pair-wise comparison matrix of factors, sub-factors, and strategies, through the linguistic terms shown in Table 1.

The neutrosophic scale is attained according to expert opinions. The neutrosophic pair-wise comparison matrix of factors, sub-factors, and strategies is described in Equation 7.

Step 3: Check the consistency of experts' judgments.

If the pair-wise comparison matrix has a transitive relation, i.e., $a_{ik} = a_{ij}a_{jk}$ for all i,j, and k, then the comparison matrix is consistent, focusing only on the lower, median, and upper values of the triangular neutrosophic number of the comparison matrix.

Step 4: Calculate the weight of the factors from the neutrosophic pair-wise comparison matrix, by transforming it to a deterministic matrix using Equations 10 and 11. To obtain the score and the accuracy degree of $\tilde{a}_{ji}$, the following equations are used:

$$S(\tilde{a}_{ji}) = 1/S(\tilde{a}_{ij}) \tag{10}$$

$$A(\tilde{a}_{ji}) = 1/A(\tilde{a}_{ij}) \tag{11}$$

With compensation by the accuracy degree of each triangular neutrosophic number in the neutrosophic pair-wise comparison matrix, the following deterministic matrix is derived:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \tag{12}$$

Step 5: Determine the ranking of priorities, namely the Eigen Vector X, from the previous matrix:

1. Normalize the column entries by dividing each entry by the sum of the column.
2. Take the total of the row averages.

Note that Step 3 refers to considering the use of the calculation of the *Consistency Index* (CI) when applying this technique, which is a function depending on λ_{max}, the maximum eigenvalue of the matrix. Saaty establishes that the consistency of the evaluations can be determined by equation $CI = \frac{\lambda_{max} - n}{n-1}$, where n is the order of the matrix. In addition, the *Consistency Ratio* (CR) is defined by the equation CR = CI/RI, where RI is given in Table 2.

Table 2: RI associated with every order**.**

Order (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

If $CR \leq 0.1$ then experts' evaluation is sufficiently consistent and hence NAHP can be used. Applying this procedure to matrix A in Equation 12.

3 Results

The allocation of intensive care (ICU) beds is a critical task that requires consideration of several criteria to ensure that patients receive appropriate care based on their health status. In this sense, to evaluate the criteria to be considered within the model to be carried out, the experience of 4 experts in the area is used. The criteria used were selected through rounds of brainstorming for subsequent analysis regarding incorporation into the model and subsequently, certain subcriteria of necessary inclusion were derived.

Once the criteria and sub-criteria to be considered have been determined, they are evaluated based on which ones have the greatest impact on the allocation of resources. The analysis is first carried out for each of the criteria and later it is carried out for the sub-criteria, in order to rank them. By applying equation 9 to the resulting data, the numerical matrix is obtained to which the normal procedure of the AHP method is applied, the consistency ratio is verified, and the weight matrix W is obtained for these criteria as shown in Table 3.

Table 3: Criteria evaluation matrix, according to the experts' criteria and weights associated with each criterion.

	Medical history	Special monitoring needs	Severity level	Need for additional resources	**Weights**
Medical history	$\tilde{1}$	$\tilde{3}$	$1/\tilde{5}$	$\tilde{1}$	**0.183**
Special monitoring needs	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$1/\tilde{3}$	**0.112**
Severity level	$\tilde{5}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	**0.501**
Need for additional resources	$\tilde{1}$	$\tilde{3}$	$1/\tilde{3}$	$\tilde{1}$	**0.204**

Tables 4 to 7 show the summary of the same procedure applied to each of the subcriteria within each criterion to determine their relative importance among them. For reasons of convenience when processing the data, their numbering is used instead of literal sentences.

Table 4. Evaluation matrix of medical history subcriteria. CR= 0.082

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	Weight(w)
A1	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$1/\tilde{3}$	1/3	1/3	v	**0.043**
A2	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{5}$	**0.049**
A3	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	**0.128**
A4	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{5}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{5}$	**0.042**
A5	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$1/\tilde{5}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	**0.060**
A6	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{3}$	$1/\tilde{3}$	**0.083**
A7	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{5}$	$\tilde{5}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$1/\tilde{5}$	$\tilde{1}$	**0.135**
A8	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	**0.125**
A9	$\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$1/\tilde{3}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	**0.070**
A10	$\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{5}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	**0.094**
A11	$\tilde{5}$	$\tilde{5}$	$\tilde{1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	**0.170**

Table 5. Evaluation matrix of the subcriteria referring to special monitoring needs. RC= 0.021

	N1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	*Weight*(w)
N 1	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$1/\tilde{5}$	$1/\tilde{3}$	**0.072**
N 2	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{5}$	**0.054**
N 3	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{3}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	**0.105**
N 4	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	**0.104**
N 5	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	**0.140**
N 6	$\tilde{1}$	$\tilde{3}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{3}$	**0.070**
N 7	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	**0.151**
N 8	$\tilde{5}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	**0.154**
N 9	$\tilde{3}$	$\tilde{5}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	**0.150**

Table 6. Evaluation matrix of the subcriteria referring to the patient's level of severity. RC= 0.023

	G1	G 2	G 3	G 4	G 5	G 6	G 7	G8	G 9	G 10	**Weight (w)**
G 1	$\tilde{1}$	$\tilde{3}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{5}$	$1/\tilde{5}$	$1/\tilde{5}$	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{3}$	**0.043**
G 2	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{5}$	$1/\tilde{5}$	$1/\tilde{3}$	$1/\tilde{5}$	$1/\tilde{5}$	$\tilde{1}$	**0.036**
G 3	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	**0.127**
G 4	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{5}$	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{3}$	$\tilde{1}$	**0.047**
G 5	$\tilde{5}$	$\tilde{5}$	$\tilde{1}$	$\tilde{5}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	**0.157**
G 6	$\tilde{5}$	$\tilde{5}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	**0.131**
G 7	$\tilde{5}$	$\tilde{3}$	$1/\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	**0.106**
G 8	$\tilde{3}$	$\tilde{5}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	**0.134**
G 9	$\tilde{3}$	$\tilde{5}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	**0.136**
G 10	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	**0.084**

Table 7. Weaknesses evaluation matrix. CR= 0.063

	AN1	AN 2	AN 3	AN 4	AN 5	AN 6	**Weight (w)**
AN 1	$\tilde{1}$	$1/\tilde{3}$	1/5	$\tilde{3}$	$1/\tilde{3}$	$1/\tilde{5}$	**0.071**
AN 2	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$1/\tilde{5}$	$1/\tilde{5}$	**0.112**
AN 3	$\tilde{5}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	**0.212**
AN 4	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{5}$	$1/\tilde{5}$	**0.050**
AN 5	$\tilde{5}$	$\tilde{5}$	$\tilde{1}$	$\tilde{5}$	$\tilde{1}$	$\tilde{1}$	**0.264**
AN 6	$\tilde{5}$	$\tilde{5}$	$\tilde{1}$	$\tilde{5}$	$\tilde{1}$	$\tilde{1}$	**0.291**

Once the individual assessments are obtained, the global analysis is carried out as shown in Table 8.

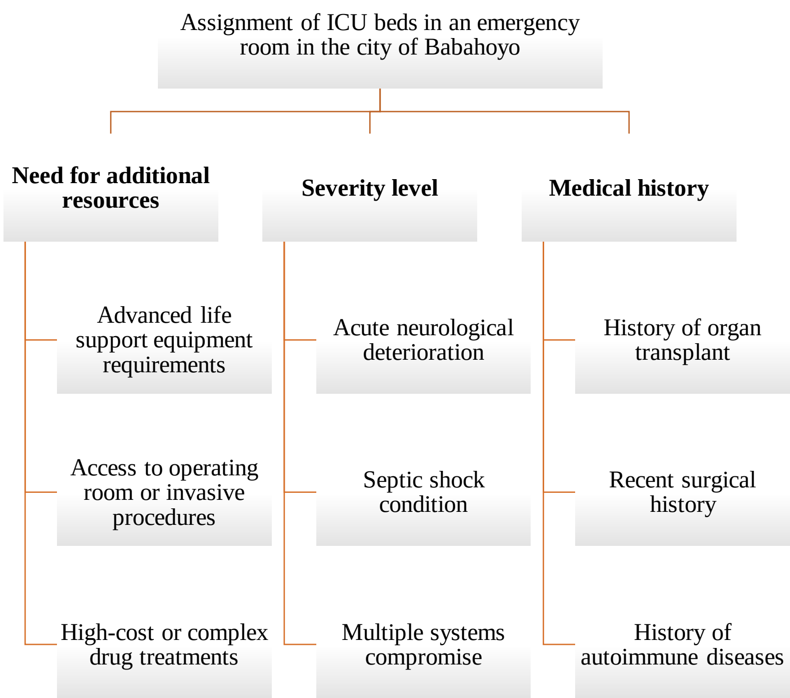
Table 8. Summary of the global evaluations of the criteria and sub-criteria

Criteria	Weight (W)	Subcriteria	**Weight (w)**	**Overall Value**
Special monitoring needs	0.112	Continuous cardiac monitoring needs	0.043	0.005
		Respiratory monitoring needs	0.049	0.005
		Neurological monitoring	0.128	0.014
		Fluid and electrolyte monitoring	0.042	0.005
		Metabolic monitoring needs	0.060	0.007
		Medication monitoring	0.083	0.009
		Hemodynamic monitoring requirements	0.135	0.015
		Monitoring liver and kidney function	0.125	0.014
		Needs to monitor sedation and delirium levels	0.070	0.008
		Intra-abdominal pressure monitoring requirements	0.094	0.010
		Cerebral oxygen saturation monitoring needs	0.170	0.019
Need for additional resources	0.204	Mechanical ventilation requirements	0.072	0.014
		Mechanical circulatory support needs	0.054	0.011
		Continuous evaluation of medical images	0.105	0.021
		Pediatric intensive care	0.104	0.021
		Invasive monitoring devices	0.140	0.028
		Specialized personnel resources	0.070	0.014

Criteria	Weight (W)	Subcriteria	**Weight (w)**	**Overall Value**
		Treatments with high-cost or complex medications	0.151	0.030
		Access to the operating room or invasive procedures	0.154	0.031
		Advanced life support equipment requirements	0.150	0.030
Severity level	0.501	Hemodynamic instability	0.043	0.021
		Severe respiratory insufficiency	0.036	0.018
		Severe trauma	0.127	0.063
		Severity score on evaluation scales	0.047	0.024
		Septic shock	0.157	0.078
		Need for cardiopulmonary resuscitation	0.131	0.065
		Severity score on evaluation scales	0.106	0.053
		Acute neurological deterioration	0.134	0.067
		Multiple system compromise	0.136	0.068
		Chronic medical conditions	0.084	0.042
Medical history	0.183	History of infectious diseases	0.071	0.013
		Chronic diseases	0.112	0.020
		History of autoimmune diseases	0.212	0.038
		Drug allergies	0.050	0.009
		Recent surgical history	0.264	0.047
		History of organ transplant	0.291	0.052

From these results, it is possible to create the hierarchical tree of the developed model, as shown in Figure 1.

Figure 1: Hierarchical tree of the proposed model.



After establishing this model, it is possible to proceed with the steps for the application of the AHP method for the allocation of ICU beds, depending on the criteria selected by the experts.

7 Discussion

The potential of using neutrosophic logic in the hospital setting for complex decision-making, especially in the allocation of resources, is a valuable tool in the efficient and equitable management of limited resources in healthcare settings. In this context, neutrosophic logic offers the ability to address the deep uncertainty and ambiguity that is often present when evaluating different criteria and factors relevant to resource allocation, such as disease severity, bed availability, burden staff workload, and budget constraints.

Neutrosophic logic enables the representation and management of incomplete and contradictory information that can arise in hospital decision-making, which is particularly beneficial when considering complex clinical cases or crises, such as epidemics or natural disasters. By allowing the creation of a model for allocating medical resources, such as hospital beds, neutrosophic logic can help healthcare professionals and hospital administrators to adequately weigh various factors, including uncertainty about patient outcomes and logistics limitations.

Furthermore, neutrosophic logic provides greater flexibility and adaptability in decision-making, allowing for the incorporation of the subjective perception of medical experts and considering fluctuations in conditions and resource availability in real time. This can result in a fairer and more efficient allocation of medical resources, thus contributing to quality healthcare and optimized patient outcomes in an ever-changing hospital environment.

Conclusion

Neutrosophy is a valuable tool for decision-making in all areas of life that require a clear understanding of the uncertainties and inaccuracies of the real world. In this study, neutrosophic logic was applied to create a model for allocating beds in the Intensive Care Unit of an emergency room in Babahoyo, supported by the AHP method. The AHP method, combined with the proposals from neutrosophy, has enabled the development of a model for making informed and fair decisions in cases of ICU bed shortages. This ensures optimum patient care and efficient resource management. The research results not only confirm the usefulness of neutrosophic logic in solving scientific problems but also highlight its practical relevance in the hospital context. This scientific approach proves to be an effective tool in managing critical resources and addressing the inherent complexity and uncertainty of medical situations. As a result, it contributes to enhancing the quality of care and effectiveness in resource management during critical situations.

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Received: October 20, 2023. **Accepted:** December 19, 2023