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Neutrosophic Models for Nursing Staff Allocation

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Abstract. In Ecuador, management of nursing staff availability in healthcare settings is challenged by variability in demand for care, uncertainty in skill assessment, and imprecision in resource planning. Therefore, the objective of this study focuses on analyzing neutrosophic nursing staff assignment models that integrate uncertainty and imprecision in decision-making, in order to improve the quality of the service in healthcare settings. For the development and modeling of the study results, the Neutrosophic TOPSIS method was applied. The results revealed the need for continuous evaluation and adaptability in staff allocation, along with the application of strategies based on neutrosophy. These conclusions highlight the value of neutrosophy as a tool to address uncertainty and imprecision in medical care by improving the quality of nursing services in Ecuador.

Keywords: Neutrosophy, nursing, healthcare environment.

1 Introduction

The review of the literature in the context of nursing staff assignment in Ecuador reveals various current indeterminacies and limitations in the consideration of uncertainty and imprecision in existing models. In such cases, neutrosophy offers a valuable tool to identify and address these limitations, allowing for a deeper and more precise understanding of the challenges in this area. Below are summarized some of the indeterminacies and limitations in the allocation of nursing staff in Ecuador:

- Variable patient demand: Demand for medical care in hospitals and health centers can vary considerably and unpredictably [1]. While neutrosophy identifies the indeterminacy in the estimation of this demand.
- Staff skills and abilities: Determining which nurses are best suited to care for certain patients based on their skills and experiences is an inherently complex process [2]. However, neutrosophy helps model this uncertainty in decision-making.
- Limited resources: The allocation of nursing staff must consider budgetary and human resource constraints. While neutrosophy allows to address the inaccuracy in the availability of resources and its impact on the allocation.
- Changes in patient condition: Patients' condition can change rapidly, introducing uncertainty in the need for care and resources required [3]. Nevertheless, neutrosophy helps quantify this variability.
- Lack of accurate data: Availability of accurate data on nursing workload and skills may be limited [4], resulting in inaccuracy in allocation planning.

In summary, the neutrosophic review of the literature on nursing staff allocation in Ecuador highlights the existing indeterminacies and limitations. To this end, an analysis and comparison of the results of neutrosophic models of nurse staffing with those of traditional approaches is carried out. At this point, the focus is on highlighting the advantages of neutrosophy in the management of uncertainty and imprecision (see Table 1).

Table 1: Neutrosophic models vs traditional approaches. Source: own elaboration.

Aspects	Neutrosophic models	Traditional approaches
Uncertainty management	Neutrosophic models address uncertainty explicitly by representing it using neutrosophic sets. This allows for precise management of uncertainty in the allocation of nursing staff. So, it can be especially useful in healthcare settings where patient demand is	Traditional approaches tend to simplify uncertainty or ignore it completely. This can lead to suboptimal allocations and a failure to adapt to variations in

Aspects	Neutrosophic models	Traditional approaches
	variable and staff availability is limited.	healthcare demand.
Consideration of imprecision	Neutrosophic logic captures the imprecision inherent in assessing staff skills and determining demand for care. This allows for a more realistic and accurate allocation of resources, by considering the limits of knowledge and variability in evaluations.	Traditional approaches often assume accurate assessments of skills and demand. So, it can lead to suboptimal decisions when these assessments are not accurate.
Continuous adaptation	Neutrosophic models promote continuous improvement because they can be adjusted and adapted based on data and changing conditions in the healthcare environment [5-14]. This allows for more flexible and effective staff allocation.	Traditional approaches can be rigid and lack the ability to adapt to changing situations. This can result in inefficiencies and problems in the quality of care [6].
Improved quality and efficiency	Appropriate management of uncertainty and imprecision using neutrosophic models can lead to significant improvement in the quality of care and the efficiency of nursing staff allocation [7-15-16]. This is because of a more precise allocation of resources and greater adaptability to changing conditions.	Traditional approaches can achieve acceptable results under stable conditions but may be less effective in situations of high variability and rapid change.

In summary, using neutrosophic models for nursing staff allocation offers significant advantages in managing uncertainty and imprecision compared to traditional approaches. They allow for more precise and adaptable decision-making. So, it leads to an improvement in the efficiency and quality of medical care. Based on the deficiencies detected, it is necessary to apply a neutrosophic analysis due to the level of indeterminations existing in the study. Therefore, this study defines as its main objective:

- Analyze neutrosophic nursing staff allocation models that integrate uncertainty and imprecision in decision-making to improve the quality of the service in healthcare settings.

Specific objectives:

- Determine the factors that affect the analyzed variable.
- Perform modeling using the neutrosophic TOPSIS method to determine the most effective alternative.
- Project solutions based on improving nursing staff allocation models in Ecuador.

2 Materials and methods

2.1 Neutrosophic Statistics and TOPSIS

This section details the main concepts and techniques that will be used in the present study.

Definition 1. Let X be a universe of discourse. A Neutrosophic Set (NS) is characterized by three membership functions [8], $u_A(x), r_A(x), v_A(x): X \rightarrow$] -0,1+[, which satisfy the condition $-0 \leq inf u_A(x) + inf r_A(x) + inf v_A(x)\ sup\ u_A(x) + sup\ \ r_A(x) + \sup v_A(x) \leq 3^+$ for all $x \in X$. $u_A(x), r_A(x)\ and\ v_A(x)$ denote the true, indeterminate, and false membership functions of x in A, respectively, and their images are standard or non-standard subsets of $] - 0,1 + [$.

Definition 2. Let X be a universe of discourse. A Single-Valued Neutrosophic Set (SVNS) A over X is an object of the form:

$$A = \{\langle x, u_A(x), r_A(x), v_A(x) \rangle : x \in X\} \quad (1)$$

Where $u_A, r_A, v_A: X \rightarrow [0,1]$, satisfy condition $0 \leq u_A(x), r_A(x), v_A(x) \leq 3$ for all $x \in X$. $u_A(x), r_A(x)\ y\ v_A(x)$ denote the true, indeterminate, and false membership functions of x in A respectively. For convenience, a Single-Valued Neutrosophic Number (SVNN) will be expressed as A = (a, b, c), where a, b, c [0,1] and satisfies 0 ≤ a + b + c ≤ 3.

The SVNSs arose with the idea of applying neutrosophic sets for practical purposes. Some operations between SVNN are expressed below:

Given A1 = (a1, b1, c1) and A2 = (a2, b2, c2) two SVNN, the sum between A1 and A2 is defined as:

$$A_1\ \ A_2 = (a_1 + a_2 - a_1 a_2, b_1 b_2, c_1 c_2) \quad (2)$$

Given A1 = (a1, b1, c1) and A2 = (a2, b2, c2) two SVNN, the multiplication between A1 and A2 is defined as:

$$A_1\ \ A_2 = (a_1 a_2, b_1 + b_2 - b_1 b_2, c_1 + c_2 - c_1 c_2) \quad (3)$$

The product of a positive scalar with a SVNN, A = (a, b, c) is defined by:

$$A = (1 - (1 - a), b, c) \quad (4)$$

Let $\{A_1, A_2, \ldots, A_n\}$ be a set of n SVNN, where Aj = (aj, bj, cj) (j = 1, 2, …, n), then the Single-Valued Neutrosophic Weighted Average Operator (SVNWAO) over the set is calculated through the following equation:

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1 - \prod_{j=1}^{n} (1 - a_j)^{\lambda_j}, \prod_{j=1}^{n} b_j^{\lambda_j}, \prod_{j=1}^{n} c_j^{\lambda_j}, \right) \quad (5)$$

Where λ_j is the weight of Aj, [0, 1] λ_j ∈[0, 1] and $\sum_{j=1}^{n} = 1$.

Definition 3. Let $A^* = (A_1^*, A_2^*, \ldots, A_n^*)$ be a vector of n SVNN such that $A_j^* = (a_1^*, b_2^*, c_j^*)(j = 1,2, \ldots, n)$ and $B_i = (B_{i1}, B_{i2}, \ldots, B_{im})(i = 1,2, \ldots, m)$ be m vectors of n SVNN such that $B_{ij} = (a_{ij}, b_{ij}, c_{ij})$ (i = 1, 2, …,m)(j = 1, 2, …, n). Then the Separation Measure between Bi and A* is calculated by the following Equation:

$$s_i = \left(\frac{1}{3} \sum_{j=1}^{n} \left\{ (a_{ij} - a_j^*)^2 + (b_{ij} - b_j^*)^2 + (c_{ij} - c_j^*)^2 \right\} \right)^{\frac{1}{2}} \quad (6)$$

Where i=(1, 2, ..., m)

Definition 4. Let A = (a, b, c) be an SVNN, the scoring function S of an SVNN, based on the true membership degree, the indeterminate membership degree, and the false membership degree, is defined by the following Equation :

$$S(A) = \frac{1 + a - 2b - c}{2} \quad (7)$$

Where S(A) ∈ [-1, 1]

In this paper, linguistic terms will be associated with SVNN, so that experts can carry out their evaluations in linguistic terms, which is a more natural way of assessment for humans. Therefore, the scales shown in Table 2 will be considered.

Table 2: Linguistic terms that represent the weight of the importance of alternatives. Source: own elaboration.

Linguistic term	SVNN
Very Important (VI)	(0.90, 0.15, 0.10)
Important (I)	(0.85,0.20,0.20)
Medium (M)	(0.50,0.45,0.50)
Not Important (NI)	(0.35,0.85,0.75)
Very Not Important (VNI)	(0.10,0.90,0.95)

The TOPSIS method for SVNN consists of the following, assuming that $A = \{\rho_1, \rho_2, \ldots, \rho_m\}$ is a set of alternatives and $G = \{\beta_1, \beta_2, \ldots, \beta_m\}$ is a set of criteria, the following steps will be carried out:

Step 1: Determine the weight of the experts. To do this, the specialists evaluate according to the linguistic scale that appears in Table 2, and the calculations are carried out with their associated SVNN, let At = (at, bt, ct) be the SVNN corresponding to the *t-th* decision-maker (t = 1, 2 , …, k). The weight is calculated by the following formula:

$$\lambda_t = \frac{a_t + b_t \left(\frac{a_t}{a_t + c_t} \right)}{\sum_{t=1}^{k} a_t + b_t \left(\frac{a_t}{a_t + c_t} \right)} \quad (8)$$

$\lambda_t \geq 0$ and $\sum_{t=1}^{k} \lambda_t$

Step 2: Construction of the neutrosophic decision matrix of aggregated single values. This matrix is defined by $D = \sum_{t=1}^{k} \lambda_t D^t$, where dij = (uij, rij, vij) and is used to aggregate all individual evaluations. dij is calculated as the aggregation of the evaluations given by each expert $(u_{ij}^t, r_{ij}^t, v_{ij}^t)$, using the weights λ_t of each one using Equation 5. In this way, a matrix D = (dij)ij is obtained, where each dij is an SVNN (i= 1, 2, ..., m; j = 1, 2, …, n).

Step 3: Determination of the Weight of the Criteria. Suppose that the weight of each criterion is given by W = (w1, w2, …, wn), where wj denotes the relative importance of the criterion. If it is the evaluation of the criterion by the t-th expert. Then Equation 5 is used to add the weights.

Step 4: Construction of the neutrosophic decision matrix from the weighted average of unique values with respect to the criteria. $D^* = D * W, where\ d_{ij} = (a_{ij}, b_{ij}, c_{ij})$

Step 5: Calculation of the ideal positive and negative SVNN solutions. The criteria can be classified as cost type or benefit type. Let G1 be the set of benefit-type criteria and G2 be the cost-type criteria. The ideal alternatives will be defined as follows:

$$\rho^{+} = a_{\rho+w}(\beta_j), b_{\rho+w}(\beta_j), ac_{\rho+w}(\beta_j) \tag{9}$$

Denotes the positive ideal solution, corresponding to G1.

$$\rho^{-} = (a_{\rho-w}(\beta_j), b_{\rho-w}(\beta_j), ac_{\rho-w}(\beta_j)) \tag{10}$$

Denotes the negative ideal solution, corresponding to G2. Where:

$$a_{\rho+w}(\beta_j) = \begin{cases} max_i a_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ min_i a_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases} \quad a_{\rho-w}(\beta_j) = \begin{cases} min_i a_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ max_i a_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases}$$

$$b_{\rho+w}(\beta_j) = \begin{cases} max_i b_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ min_i b_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases} \quad b_{\rho-w}(\beta_j) = \begin{cases} min_i b_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ max_i b_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases}$$

$$c_{\rho+w}(\beta_j) = \begin{cases} max_i c_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ min_i c_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases} \quad c_{\rho-w}(\beta_j) = \begin{cases} min_i c_{\rho iw}(\beta_j), si\ j\epsilon G_1 \\ max_i c_{\rho iw}(\beta_j), si\ j\epsilon G_2, \end{cases}$$

Step 6: Calculation of the distances to the positive and negative SVNN ideal solutions. With the help of Equation 6, the following Equations are calculated:

$$s_i^{+} = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^{+}\right)^2 + \left(b_{ij} - b_j^{+}\right)^2 + \left(c_{ij} - c_j^{+}\right)^2\right\}\right)^{\frac{1}{2}} \tag{11}$$

$$s_i^{-} = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^{-}\right)^2 + \left(b_{ij} - b_j^{-}\right)^2 + \left(c_{ij} - c_j^{-}\right)^2\right\}\right)^{\frac{1}{2}} \tag{12}$$

Step 7: Calculation of the Coefficient of Proximity (CP). The CP of each alternative is calculated with respect to the positive and negative ideal solutions.

$$\widetilde{\rho_J} = \frac{s^{-}}{s^{+} + s^{-}} \tag{13}$$

Where $0 \leq \widetilde{\rho_J} \leq 1$.

Step 8: Determination of the order of the alternatives.

They are ordered according to the value of $\widetilde{\rho_J}$. The alternatives are ordered from highest to lowest, under the condition that $\widetilde{\rho_J} \rightarrow 1$ is the optimal solution.

Additionally, for statistical processing, the following formula was used to calculate the sample size.

$$n = \frac{ZNpq}{E^2(N-1) + Z^2pq} \tag{14}$$

Where: n: is the sample size, Z: is the value of the normal distribution with the assigned confidence level, E: is the desired sampling error, and N: is the population size.

3 Results

The sample size (amount of respondents) is decided using equation 14, which takes 50% or 0.05 probabilities, and the results are as follows:

- Maximum margin of error allowed=10.0%
- Population size=460
  - ✓ Size for a 95% confidence level …………………………………… 80
  - ✓ Size for a 97% confidence level…………………………………… 94
  - ✓ Size for a 99% confidence level…………………………………… 122

It was decided to work with 95% confidence, so surveys will be applied to determine the variable analyzed (see Table 3), the factors (see Table 4), alternatives and measurement criteria.

Table 3: Variable characteristics. Source: own elaboration.

Neutrosophic variable	Component	Status
Nursing staff availability	• High Availability (HA) • Moderate availability (MA) • Low availability (LA)	• It represents the degree of certainty (μ) that there are sufficient nursing staff available to meet the demand for medical care, with a low indeterminacy (η). This means that there is adequate personnel in quantity and quality. • It represents a medium degree of certainty (μ) that the availability of nursing staff could be sufficient, but with some uncertainty (η) in the assessment due to possible fluctuations in demand or availability of staff. • Represents the degree of certainty (μ) that the availability of nursing staff is insufficient to meet the demand for medical care, with a high indeterminacy (η) due to imprecision in the evaluation

The neutrosophic variable *nursing staff availability* is crucial in the context of staff allocation in medical care in Ecuador because it directly influences the ability to provide quality care and effectively manage human resources. Its neutrosophic nature reflects the uncertainty and imprecision inherent in estimating staff availability and its impact on decision-making.

While the neutrosophic factor has its own elements of origin that represent different conditions or states related to the availability of nursing staff in the health care environment in Ecuador (see Table 4). The degrees (μ, ν) indicate the level of certainty and falsity in the statement of each element, while the indeterminacy (η) reflects the uncertainty associated with the evaluation.

Table 4: Linguistic terms that represent the weight of the importance of alternatives. Source: own elaboration.

Code	Factor	Range of acceptance of element decision
F1	Demand for medical care	It depends on the circumstances and the actual evaluation.
F2	Current availability of nursing staff	It depends on the actual availability of personnel.
F3	Demand fluctuation	It depends on the real variability in demand.
F4	Staff skills assessment	It depends on the actual precision in the evaluation.
F5	Planning and resources	It depends on the actual availability of resources.

The relationship between each factor and the neutrosophic set is based on neutrosophic logic, where it is recognized that each factor can exist in different degrees of certainty, falsity and with various levels of indeterminacy. These neutrosophic factors provide a comprehensive and flexible representation of nursing staff availability, considering the uncertainty and imprecision inherent in decision-making in healthcare settings. Therefore, alternatives are proposed for the development of neutrosophic models for the assignment of nursing staff in health care settings in Ecuador (see Table 5).

Table 5: Linguistic terms that represent the weight of the importance of alternatives. Source: own elaboration.

Code	Alternatives	Scope
A1	Neutrosophic simulation.	Use neutrosophic simulation techniques to model and predict staffing scenarios based on different levels of uncertainty. This allows for more effective planning and the identification of potential bottlenecks.
A2	Neutrosophic collaboration networks.	Establish a collaborative network between hospitals and clinics to share nursing staff resources in a neutrosophic manner. Hospitals can support each other in times of high demand and compensate for staff shortages efficiently.
A3	Real-time neutrosophic assignment model.	Develop a real-time allocation system that adapts to fluctuations in healthcare demand and nurse availability. This model uses neutrosophic logic to make dynamic and efficient decisions.
A4	Neutrosophic multi-objective optimization.	Develop neutrosophic multi-objective optimization models that consider efficiency, quality of care, and costs [9]. These models allow finding optimal solutions that balance these objectives in an uncertain environment.
A5	Training in neutrosophic decision making.	Train nursing staff and administrators in the application of neutrosophic logic in decision making. So that it ensures effective implementation of the models and a solid understanding of uncertainty in staffing allocation.

These alternatives are based on neutrosophic logic to address uncertainty and imprecision in the allocation of nursing staff, so that it leads to an improvement in the efficiency and quality of care in healthcare settings in Ecuador. Combining technological and collaborative approaches with neutrosophic logic training ensures a comprehensive solution. Therefore, it is vital to evaluate each alternative based on the following criteria or skills:

- Efficiency criterion in staff allocation (ECSA): This criterion evaluates the efficiency of the alternatives in terms of the nursing staff allocation. Consideration is given to how each alternative manages staff availability to ensure optimal allocation based on demand and available resources.
- Care quality criterion (CQC): This criterion measures the quality of care provided by each alternative. Evaluates how each approach contributes to improved patient care, patient safety, and staff and patient satisfaction.
- Financial Sustainability Criterion (FSC): This criterion focuses on the financial sustainability of each alternative. Considers how each approach manages financial resources, controls costs, and ensures the long-term viability of nursing staffing.
- Change Adaptability Criterion (CAC): Evaluates the ability of each alternative to adapt to changes in demand, resource availability and other dynamic factors. Flexibility and the ability to respond to unforeseen situations are considered.
- Criterion of consistency with neutrosophic logic (CCNL): This criterion measures the extent to which each alternative adheres to the principles and logic of neutrosophy in the management of uncertainty and imprecision. Evaluate how neutrosophic concepts are applied in decision-making.

Once these criteria have been defined, the TOPSIS method can be applied to evaluate neutrosophic alternatives based on each criterion. This involves assigning weights to the criteria and calculating the relative performance score of each alternative compared to the others (see Tables 6 to 12). Finally, the alternatives are classified based on their TOPSIS score, which allows the optimal solution to be identified in the context of the nursing staff allocation in Ecuador.

Table 6: Calculation of the importance vector (λ_t) Source: own elaboration.

Groups	Group 1	Group 2	Group 3	Group 4	Group 5
Importance vector	(0.3,0.8,0.7)	(0.50,0.45,0.50)	(0.1,0.90,0.95)	(0.9,0.15,0.1)	(0.8,0.3,0.2)
$\boldsymbol{\lambda_t}$	0.180393484	0.189842667	0.129363256	0.248943009	0.251457584

Table 7: Single value criteria matrix. Source: own elaboration.

			Criterion 1: ECSA		
Alternatives	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**
A1	(0.3,0.8,0.7)	(0.3,0.8,0.7)	(0.3,0.8,0.7)	(0.3,0.8,0.7)	(0.8,0.3,0.2)
A2	(0.50,0.45,0.50)	(0.8,0.3,0.2)	(0.50,0.45,0.50)	(0.9,0.15,0.1)	(0.3,0.8,0.7)
A3	(0.9,0.15,0.1)	(0.9,0.15,0.1)	(0.9,0.15,0.1)	(0.9,0.15,0.1)	(0.8,0.3,0.2)
A4	(0.1,0.90,0.95)	(0.8,0.3,0.2)	(0.8,0.3,0.2)	(0.3,0.8,0.7)	(0.3,0.8,0.7)
A5	(0.3,0.8,0.7)	(0.1,0.90,0.95)	(0.8,0.3,0.2)	(0.1,0.90,0.95)	(0.50,0.45,0.50)
			Criterion 2: CQC		
A1	(0.50,0.45,0.50)	(0.3,0.8,0.7)	(0.8,0.3,0.2)	(0.50,0.45,0.50)	(0.50,0.45,0.50)
A2	(0.8,0.3,0.2)	(0.50,0.45,0.50)	(0.50,0.45,0.50)	(0.1,0.90,0.95)	(0.8,0.3,0.2)
A3	(0.8,0.3,0.2)	(0.9,0.15,0.1)	(0.8,0.3,0.2)	(0.8,0.3,0.2)	(0.9,0.15,0.1)
A4	(0.1,0.90,0.95)	(0.8,0.3,0.2)	(0.1,0.90,0.95)	(0.8,0.3,0.2)	(0.50,0.45,0.50)
A5	(0.3,0.8,0.7)	(0.1,0.90,0.95)	(0.50,0.45,0.50)	(0.50,0.45,0.50)	(0.3,0.8,0.7)
			Criterion 3: FSC		
A1	(0.8,0.3,0.2)	(0.8,0.3,0.2)	(0.9,0.15,0.1)	(0.3,0.8,0.7)	(0.8,0.3,0.2)
A2	(0.50,0.45,0.50)	(0.3,0.8,0.7)	(0.50,0.45,0.50)	(0.9,0.15,0.1)	(0.3,0.8,0.7)
A3	(0.9,0.15,0.1)	(0.9,0.15,0.1)	(0.9,0.15,0.1)	(0.8,0.3,0.2)	(0.9,0.15,0.1)
A4	(0.3,0.8,0.7)	(0.1,0.90,0.95)	(0.8,0.3,0.2)	(0.9,0.15,0.1)	(0.8,0.3,0.2)
A5	(0.8,0.3,0.2)	(0.9,0.15,0.1)	(0.3,0.8,0.7)	(0.1,0.90,0.95)	(0.9,0.15,0.1)
			Criterion 4: CAC		
A1	(0.3,0.8,0.7)	(0.8,0.3,0.2)	(0.9,0.15,0.1)	(0.3,0.8,0.7)	(0.9,0.15,0.1)
A2	(0.1,0.90,0.95)	(0.9,0.15,0.1)	(0.1,0.90,0.95)	(0.8,0.3,0.2)	(0.1,0.90,0.95)
A3	(0.8,0.3,0.2)	(0.9,0.15,0.1)	(0.9,0.15,0.1)	(0.8,0.3,0.2)	(0.8,0.3,0.2)
A4	(0.9,0.15,0.1)	(0.50,0.45,0.50)	(0.8,0.3,0.2)	(0.1,0.90,0.95)	(0.8,0.3,0.2)
A5	(0.8,0.3,0.2)	(0.1,0.90,0.95)	(0.3,0.8,0.7)	(0.9,0.15,0.1)	(0.3,0.8,0.7)
			Criterion 5: CCNL		
A1	(0.50,0.45,0.50)	(0.9,0.15,0.1)	(0.8,0.3,0.2)	(0.9,0.15,0.1)	(0.8,0.3,0.2)

	Criterion 1: ECSA				
A2	(0.3,0.8,0.7)	(0.1,0.90,0.95)	(0.3,0.8,0.7)	(0.50,0.45,0.50)	(0.3,0.8,0.7)
A3	(0.9,0.15,0.1)	(0.8,0.3,0.2)	(0.9,0.15,0.1)	(0.9,0.15,0.1)	(0.9,0.15,0.1)
A4	(0.1,0.90,0.95)	(0.3,0.8,0.7)	(0.1,0.90,0.95)	(0.8,0.3,0.2)	(0.50,0.45,0.50)
A5	(0.8,0.3,0.2)	(0.8,0.3,0.2)	(0.9,0.15,0.1)	(0.9,0.15,0.1)	(0.1,0.90,0.95)

Table 8: Decision Table added by experts. Source: own elaboration.

Alt.	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
A1	(0.48916;0.62514;0.51084)	(0.5266;0.47629;0.4734)	(0.75024;0.35012;0.24976)	(0.737;0.351;0.263)	(0.8259;0.2381;0.1741)
A2	(0.69369;0.3663;0.30631)	(0.61036;0.44886;0.39492)	(0.61144;0.44127;0.38856)	(0.5922;0.4872;0.4204)	(0.3248;0.7089;0.6822)
A3	(0.88096;0.17856;0.11904)	(0.85271;0.22094;0.14729)	(0.88117;0.17825;0.11883)	(0.8397;0.2405;0.1603)	(0.8859;0.1711;0.1141)
A4	(0.50896;0.59751;0.49585)	(0.59873;0.46687;0.40804)	(0.7193;0.37119;0.2836)	(0.6946;0.3759;0.3095)	(0.491;0.5624;0.5176)
A5	(0.38925;0.64209;0.62541)	(0.35355;0.65807;0.65312)	(0.74813;0.32973;0.25529)	(0.6392;0.4518;0.3645)	(0.7754;0.3042;0.2277)

Table 9: Weights assigned by the experts to each criterion. Source: own elaboration.

Criteria	Pesos
Criterion 1	(0.892;0.15842;0.11406)
Criterion 2	(0.85136;0.20724;0.1501)
Criterion 3	(0.892;0.15842;0.11406)
Criterion 4	(0.81257;0.23173;0.22027)
Criterion 5	(0.85691;0.19234;0.15917)

Table 10: SVNN weighted decision matrix. Source: own elaboration.

Alternative	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
A1	(0.43633;0.68453;0.56663)	(0.44833;0.58482;0.55244)	(0.66921;0.45307;0.33533)	(0.59886;0.50139;0.42534)	(0.70772;0.38464;0.30556)
A2	(0.61877;0.46669;0.38543)	(0.51964;0.56308;0.48574)	(0.5454;0.52978;0.4583)	(0.4812;0.60603;0.54807)	(0.27832;0.76489;0.73278)
A3	(0.78582;0.30869;0.21952)	(0.72596;0.38239;0.27528)	(0.786;0.30843;0.21934)	(0.68232;0.4165;0.34526)	(0.75914;0.33053;0.25511)
A4	(0.45399;0.66127;0.55335)	(0.50973;0.57736;0.49689)	(0.64162;0.47081;0.36531)	(0.56441;0.52052;0.4616)	(0.42074;0.64657;0.59438)
A5	(0.34721;0.69879;0.66814)	(0.301;0.72893;0.70519)	(0.66733;0.43591;0.34023)	(0.51939;0.57883;0.50448)	(0.66445;0.43803;0.35063)

Table 11: Positive and negative ideal values by criterion. Source: own elaboration.

Criteria	Ideal value +	Ideal value -
C1	(0.78582,0.30869,0.21952)	(0.34721,0.69879,0.66814)
C2	(0.72596,0.38239,0.27528)	(0.301,0.72893,0.70519)
C3	(0.786,0.30843,0.21934)	(0.5454,0.52978,0.4583)
C4	(0.68232,0.4165,0.34526)	(0.4812,0.60603,0.54807)
C5	(0.75914,0.33053,0.25511)	(0.27832,0.76489,0.73278)

Table 12: Determine the distances to the negative and positive solutions. Source: own elaboration.

Alternatives	s_i^+	s_i^-	$\widetilde{\rho_J}$	Order
A1	0.545713021	0.2932663	0.349551	3
A2	0.723175927	0.4190551	0.366874	2
A3	0.251680279	0.6954157	0.734261	1
A4	0.665887559	0.3003939	0.310876	4
A5	0.697755424	0.1926264	0.216341	5

After calculating the TOPSIS scores for each alternative, it is observed that the *real-time neutrosophic allocation model* alternative obtains the highest score in terms of the proposed evaluation criteria. Therefore, this alternative is the most appropriate to manage uncertainty and imprecision in decision-making, by aligning with neutrosophic logic and established importance criteria. Based on the results, it was decided to promote the alternative and address the indeterminacies related to the nursing staff allocation models in Ecuador. Therefore, the defined alternative must have the following actions integrated into the neutrosophic solutions:

- Actions on the management of demand for nursing staff (see Table 13)
- Actions on decision-making in the nursing staff allocation (see Table 14)
- Preliminary proposal based on a neutrosophic optimization algorithm for the nursing staff allocation.

Table 13: Actions on the management of demand for nursing staff. Source: own elaboration.

Actions	Neutrosophic Solution	Benefits
Continuous demand monitoring	Implement a continuous healthcare demand monitoring system that uses real-time data analysis and tracking technologies. This helps maintain an accurate and up-to-date record of demand in the healthcare environment.	By having real-time information, the indeterminacy (η) related to demand estimation will be reduced. Adjustments can be made in a timely manner to meet changing healthcare needs.
Flexible staff and mobile resources	Establish a team of flexible nursing staff and mobile resources that can be mobilized according to demand [10]. This could include male or female nurses who can be moved from one location to another based on need.	By having mobile staff and resources, the availability (μ) of nursing staff can be adapted more efficiently to fluctuating demand. In such a way as to minimize uncertainty in planning.
Demand forecasting models.	Develop healthcare demand forecasting models based on historical data and trends. These models could use advanced data analytics and machine learning techniques to predict future demand.	Forecasting models help reduce uncertainty (η) by providing more accurate estimates of demand.
Training and continuous evaluation	Invest in the continuous training of nursing staff and in the periodic evaluation of their skills. This ensures that the assessment of staff skills is more accurate and that their ability to deal with diverse situations can be trusted.	An accurate assessment of skills (μ) reduces uncertainty (η) in staff allocation. So the competence of the nursing team is reliable [11].
Communication and interdisciplinary collaboration	Foster interdisciplinary communication and collaboration between different healthcare departments, such as physicians, nurses, and administrators. This helps share information and resources more effectively [12].	Interdisciplinary collaboration reduces indeterminacy (η) by enabling better coordination of resources and faster response to changes in demand.

These neutrosophic solutions are designed to address the uncertainty and imprecision in the variable *availability of nursing staff* in Ecuador, by focusing on the *healthcare demand* factor. By implementing the actions in the *real-time neutrosophic allocation model*, efficient and effective allocation of human resources in healthcare settings can be achieved. The integration of solutions into neutrosophic models improves the quality and adaptive capacity of the health system.

Table 14: Actions on decision-making in the nursing staff allocation. Source: own elaboration.

Actions	Neutrosophic Solution
Continuous training in neutrosophic logic	Provide an ongoing training program to all nursing staff and healthcare administrators to improve their understanding of neutrosophic logic and its application in decision-making. This would include updated courses, workshops and training materials to ensure staff are aware of the latest neutrosophic practices and approaches.
Development of neutrosophic tools	Design specialized tools and software that allow healthcare professionals to apply neutrosophic logic effectively in staffing. These tools could include neutrosophic optimization software and neutrosophic-based decision support systems [13].
Collaboration with higher education institutions	Establish partnerships with universities and nursing schools to develop academic programs that integrate neutrosophic logic in the training of nurses and health professionals. This ensures that the next generation of professionals is prepared to address uncertainty and imprecision in staffing.
Audits and neutrosophic evaluations	Conduct regular audits and evaluations of staff allocation using neutrosophic approaches. This allows you to identify areas for improvement and adjust staffing strategies on an ongoing basis, considering variability in demand and staff availability.
Development of neutrosophic decision-making committees	Establish committees specialized in neutrosophic logic that are responsible for making decisions related to the nursing staff allocation. These committees can ensure that sound neutrosophic approaches are followed and help mitigate uncertainty in decisions.

These neutrosophic solutions can enhance the alternative *real-time neutrosophic allocation model*, by addressing indeterminacies and improving the management of the neutrosophic variable *availability of nursing staff*. By combining training, tool development, and collaboration with academic institutions, more efficient staff allocation and higher quality healthcare can be achieved in healthcare settings in Ecuador.

In the solution, a neutrosophic optimization algorithm base for the nursing staff allocation must be proposed. The algorithm would be based on neutrosophic logic and would consider uncertainty in healthcare demand and the abilities of staff to make efficient allocation decisions. Neutrosophic membership functions would be used to evaluate the appropriateness of the assignments.

1. Initialization: Initialize a neutrosophic assignment matrix that represents the appropriateness of assigning each nurse to a patient based on the demand for care and staff skills. This matrix would be updated during the optimization process.
2. Optimization:
   - Step 1: Neutrosophic evaluation: For each cell of the allocation matrix, calculate the degree of suitability (μ) of the allocation based on demand and skills. Use neutrosophic logic to determine the value of μ, ν and η.
   - Step 2: Operational constraints: Apply operational constraints, such as nurse and patient availability, to ensure assignments are feasible.
   - Step 3: Neutrosophic Optimization: Use a neutrosophic optimization algorithm that maximizes the efficiency and quality of the assignment. This involves finding a combination of assignments with the highest possible μ values, which considers the operational constraints.
3. Results:
   - Obtain the final assignment matrix, which represents the optimal nursing staff assignments considering uncertainty and operational constraints.
4. End of algorithm:
   - The algorithm stops when an optimal allocation is reached or after a predetermined number of iterations.

This neutrosophic optimization algorithm leverages neutrosophic logic to quantify and manage uncertainty in nursing staffing assignment. Assignments are evaluated using neutrosophy, considering both variable health care demand and staff skills. Operational restrictions are applied to ensure the feasibility of assignments. The end result is an efficient, high-quality allocation that appropriately reflects the uncertainty present in the healthcare environment.

Conclusion

The application of neutrosophy in the management of nursing staff availability in Ecuador proves to be a valuable approach to address the uncertainty and imprecision inherent in healthcare. Neutrosophic models allow for a more complete representation of reality and decision-making in a dynamic and complex healthcare environment.

Continuous assessment of health care demand and nursing staff skills is essential to reduce indeterminacy in decision-making. The results obtained from the modeling of the TOPSIS neutrosophic method revealed that the alternative *real-time neutrosophic assignment model* is aligned with the actions on demand management and decision-making in the nursing staff allocation.

Real-time monitoring systems, constant training and feedback are essential elements to improve staff availability and quality of care. Flexibility in staff allocation and adaptability of assignment models are essential to manage variability in demand. Neutrosophic models and alternatives designed to adapt to changes in demand are crucial to guarantee efficient and high-quality healthcare in Ecuador.

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